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COLONIAL DEVELOPMENT AND INTERNATIONAL CO-OPERATION

THE increasing tempo of development in Colonial territories, and also the urgent need for integrating their economy with that of Europe as a whole, have given added importance to published studies of Colonial administration. A recent one*, by Mr. Martin Wight, is the first study made of a Colonial legislative council in action, and has political as well as constitutional significance. Mr. Wight attempts to put the legislative council in its place against the life and society of one of the most progressive British dependencies in Africa. Beginning with a factual study of the history and practice of the legislative council over the twenty years from 1925, it affords a valuable introduction to the appraisal of the new constitution of 1946 in which the legislative council became the legislature for Ashanti as well as for the Gold Coast Colony, and was at the same time transformed into a representative legislature in which the official majority has been replaced by an unofficial, elected, African majority.

Mr. Wight comments on the significance of this first introduction of representative government into Africa outside the colonies of white settlement, in the general context of British Colonial government. His book well indicates how this step is in keeping with the spirit that has inspired British Colonial government since Sir James Stephen's days, and should do something to convince Africans that we share with them both the ultimate vision and something of the ardour and urgency which they are bringing to its realization. In seizing on the legislative council, which has long been the growing point of constitutional development in the Colonies, for the starting point of this series, the Colonial Research Committee appointed by Nuffield College could scarcely have demonstrated better the capacity of such research on contemporary political and economic questions to contribute to an understanding of these problems by both the white and the coloured peoples, and to the effective collaboration which is required for their solution.

A second reason for welcoming this survey of Colonial administration is the value of such a conspectus in relation to the latest approach to international co-operation in this field. The survey has its place in rebutting the uninformed criticism which has sometimes come into discussions related to the trusteeship proposals in the United Nations Organisation ; but it is even more pertinent in regard to such developments as those on which the Foreign Secretary just touched in his speech in the House of Commons on January 22. Pointing out that the organisation of Western Europe requires economic support, he emphasized that such support involves the closest possible collaboration between the British Commonwealth and overseas territories, French, Dutch, Belgian and Portuguese as well as British. These

* The Gold Coast Legislative Council. By Martin Wight. (Studies in Colonial Legislatures, Vol. 2 : Published under the auspices of Nuffield College.) Pp. 285. (London : Faber and Faber, Ltd., 1947.) 12s. 6d. net.

overseas territories are large primary producers, with a standard of life which is rising and is capable of great development. They have raw materials, food and resources which can be turned to very great common advantage, and Mr. Bevin suggested that to enable Western Europe to achieve its balance of payments and a world equilibrium, it is essential that those resources should be made available and the exchange between them carried out correctly.

Mr. Bevin did not pursue this idea into any detail. He affirmed that there is no conflict between the social and economic development of these overseas territories to the advantage of their people, and their development as a source of supplies for Western Europe as a contributor to the balance of payments. He merely indicated the Government's intention, if the Marshall Plan for American aid to Europe is accepted, to develop economic co-operation between Western European countries step by step, to develop the resources of the territories with which we are associated, and to build up a system of priorities which will yield the quickest, most effective and most lasting results for the whole world; it is also hoped that other countries with dependent territories will do the same in association with us.

Mr. Bevin's vision of the tremendous resources stretching through Europe, the Middle East and Africa, to the Far East, being brought together with the object of making the whole world richer and safer, involves economic and social planning on a bolder and more imaginative scale than the world has yet seen. None the less, the opportunity may well be there, and although this imaginative passage in his speech has largely escaped notice, there is already evidence that the European Powers concerned in Colonial administration are drawing closer together. The Royal Institute of International Affairs has recently published* a series of papers on Colonial administration read at King's College, London, in November and December 1946. Contributions from French, Dutch, Belgian and Portuguese administrators, side by side with Lord Hailey's review of British Colonial policy, are brought together, not merely to exchange experience and compare methods, but also to lay down general principles which may assist in the re-orientation of both policy and practice to meet the latest developments and the accelerated urge towards independence in the Colonial territories.

M. le Gouveneur H. Laurentie, in his review of recent developments in French Colonial policy, notes that in spite of frequent differences in method, Great Britain and France, inspired by their common belief in the freedom, the dignity and the reason of man, have set themselves the same goal. Dr. A. M. Joekes likewise concludes a very clear and pertinent exposition of developments in the administration of Indonesia with the hope that the assistance given by Britain in clearing up the situation in Indonesia will be a corner-stone for close and fertile co-operation between Great Britain and the Netherlands in protecting and promoting the well-being of both countries, and Dr. R. Godding's review of principles and methods now being followed in the Belgian Congo is of profound interest for such projects as the East African groundnut scheme. Scientific workers will note with special interest the reference to the National Institute for Agricultural Research in the Belgian Congo, and the emphasis laid on research. The twenty-one research and experimental stations now scattered all over that Colony, covering the various climates, soils and altitudes, have, in fact, something in common with the idea of pilot schemes developed by Dr. E. B. Worthington in his plan for Uganda.

One argument submitted by Dr. Godding in favour of the Belgian method of development is that cultivation of large modern plantations on scientific lines with up-to-date machinery affords much higher yields of produce of better quality, and in consequence a much larger return, to be ploughed back, as it were, in the form of educational, social, medical and material improvements in the native standards of living. Dr. Godding also referred to the formation of an institute of scientific research in the Congo, which would cover such fields as geology, botany, meteorology, sociology and medicine. It was intended to endow this institute with large resources, and it was hoped that it would become a kind of international research station for tropical Africa.

Such developments clearly provide substantial backing for the vigorous defence of Western democratic administration with which Dr. Godding concludes, and he too referred to the inspiration which the Western democracies draw from humanism and Christianity in this task, which, he affirmed, they would perform in a spirit of human solidarity with the coloured races. Dr. José de Almada similarly concluded his survey of Portuguese Colonial administration with the comment that the modern world leaves no room for privilege, economic domination or social injustice, any more than it can tolerate ignorance, disease, malnutrition and extreme poverty.

Lord Hailey's survey was more severely practical, emphasizing first the influences which had gone to form the modern British outlook on the general direction of Colonial policy and the measures taken to give it effect. Here he pointed out that in widening the franchise for the legislatures and extending their legislative powers, we should satisfy ourselves that such institutions are developing so as to secure the interests and confidence of the mass of the people; for this is the real measure of their success. Similarly, in admitting the native peoples to the State services and such administrative institutions as executive councils, there is the difficulty and danger of accepting those of doubtful competence or character. Again, Lord Hailey emphasized that for all the educative influence of the method of indirect rule it has its limitations, and we have not yet succeeded in making it popular with the more educated community or with the middle class or commercial elements.

* Colonial Administration by European Powers: a Series of Papers read at King's College, London, 14 November to 12 December 1946. By José de Almada, Robert Godding, Lord Hailey, A. M. Joekes and H. Laurentie. Pp. xiii+97. (London and New York: Royal Institute of International Affairs, 1947.) 4s. 6d. net.

These are matters to which due attention will doubtless be given at the conference of unofficial members of the African Legislative Councils which is to be held in London later this year. Two things, however, stand out very clearly from this series of papers: first, the general disposition to examine anew the principles which have shaped the Colonial systems of the Western democracies, and to test the adequacy of the existing structure to meet the demands which the future seems likely to make upon it; and, secondly, the large measure of implicit support in the Colonial territories for the ideas of Colonial co-operation which Mr. Bevin ventilated in the most imaginative passage of his recent speech. The chapter on international relations in the Blue Book on "The Colonial Empire, 1939–1947" (Cmd. 7167) indicates how much has already been done to prepare the way, particularly in co-operation with the French and Belgian Governments. In his speech in the House of Commons on July 29, Mr. Creech Jones particularly stressed the three years programme of conferences in technical matters between these three Governments in Africa which had already been agreed, and his words are strikingly similar to those of Mr. Bevin in regard to the larger issue of Colonial development and European needs.

Scarcely less significant, however, is the emphasis placed by Mr. Creech Jones in this speech, in the Blue Book, and also in the papers just noted, on the importance of the contribution which the scientific worker himself must make in such developments. References to research in the Blue Book and also in Mr. Creech Jones' speech show how ready should be the response of the British Government to the lead which, as Dr. Godding showed, the Belgian Government has given in certain fields. Problems of Colonial welfare and development, in their scientific aspect, were considered by several sections of the British Association at its meeting in Dundee last year, while elsewhere current discussions on game slaughter in Africa in connexion with the control of tsetse fly and trypanosomiasis have emphasized the need for proper research, to which adequate finance is the key, in yet another field, and in particular the linking of research with authoritative administrative co-operation.

There are, indeed, many reasons why scientific men should take an increasing interest in Colonial affairs generally. For the solution of a wide range of Colonial problems their co-operation is essential, and frequently those same problems are linked to scientific problems of fundamental importance. Further, as citizens, they cannot be indifferent to the wider implications, in the material and economic field, and in the greater task of building those Colonial and international institutions which may best serve the highest cultural and moral needs of men. In seeking thus to provide the means of safeguarding both human welfare in its physical and material sense, and the great heritage of freedom and creative achievement which Western civilization has given to the world, we shall simultaneously further the nurture and advance of science itself.

EARLY ENGLISH NATURALISTS

English Naturalists from Neckam to Ray

A Study of the Making of the Modern World. By the Rev. Charles E. Raven. Pp. x+379. (Cambridge: At the University Press, 1947.) 30*s.* net.

DR. C. E. RAVEN has followed up his remarkable work on John Ray by another, equally learned, on the early English naturalists. His purpose in the latter "began as a series of biographies. But very soon it became clear that the succession of 'lives' not only formed a very definite pattern, but that this illustrated and illuminated the progressive change in Western civilization from the medieval to the modern world." Again, "in Man's attitude to living nature the process of a gradual overcoming of superstition and fabulous tradition, and the development of the modern scientific spirit as a result, is significant and may be followed from man to man. . . . Little by little nonsense was recognized, fables were exploded, superstitions were unmasked; and the world outlook built up out of these elements fell to pieces." The thesis is not a new one, nor is it one that admits of serious dispute, but Dr. Raven has brought to bear upon it a wealth of new matter, the result of prolonged and detailed critical research. These notable additions to our knowledge have been exhumed often from little-known and unpromising sources, and they enrich and distinguish the author's bio-biographies of such naturalists as William Turner, John Caius, Thomas Penny, Thomas Mouffet, John Gerard, Edward Topsell, John Parkinson and Thomas Johnson. Dr. Raven's method, however, has one drawback. It complicates what is known as documentation, and a text frequently halted by the intercalation of bibliographical detail is apt to be tedious to follow. It is better to preserve the flow of the narrative even if it involves some sacrifice of meticulosity. In a future edition we hope to see the author's sources collected and printed in alphabetical order at the end of the text. But however this may be, historians of biology must welcome so scholarly an addition to their studies and literature.

The history and emergence of the modern outlook on science has been to many workers an attractive and fruitful field of research. The preceding or medieval period, based as it was on scholasticism, symbolism and the ingenuous acceptance of attractive but flagrant fables, was not only incapable of producing an integrated body of science, but would have been even hostile to it. As Dr. Raven remarks, the contest between an untenable tradition and the induction of the men who loved and lived by the world of plants and animals unhappily resulted in giving "for a time to the ancient writings an authority, indeed an infallibility, very damaging to progress. So long as Aristotle and Galen, or for that matter Genesis and the Apocalypse, were accepted and imposed as inerrant, it was difficult to encourage the investigation of the facts with which any real advance must begin. This delayed, though it could not prevent, the coming of the new outlook." Such is Dr. Raven's theme, and his scrutiny of the works of the early naturalists provides us with a convincing and orderly exposition of it. His most successful biography is that of William Turner, but much new light is thrown upon the works of Penny, Mouffet, Parkinson and Merrett. The book learning of Wotton, the author of a beautifully printed zoological treatise dated 1552, is rescued from undeserved obscurity, but Gerard's "Herbal" is severely, if justly, handled. Dr.

Raven, however, gives us an admirable analysis of the second edition of this famous book which had been competently revised and amended by Thomas Johnson. There are some omissions, such as Thomas Hill and Charles Butler—the latter one misses particularly, since he represents a type that Dr. Raven delights to reanimate.

Here are a few minor addenda and corrigenda. P. 58: Gaza's Latin translations of the biological works of Aristotle and Theophrastus were first printed at Venice, 1476, and Treviso, 1483. P. 145: Caius' "maculo" was evidently one of the Serranid fishes, some of which attain a length of 10 ft. The length given, 60 ft., is clearly an error, possibly for 6 ft. Caius' "ceruchus" could not be a sturgeon, but was undoubtedly the angler *Lophius*, as first pointed out by Jonathan Couch in 1862. The name is derived from the Greek and refers to the horn-like lures of the fish. Belon's "true picture of the dolphin" was first published in 1551 and only later in the "De Aquatilibus" of 1553. Hence Caius was not necessarily acquainted with the latter work. P. 180: Mouffet's unpublished engraved title-page was first described and reproduced by Mullens in 1911. P. 188: A comparison of Mouffet's woodcuts with the drawings of the original MS. is necessary in assessing the accuracy of the author. P. 220: The Su, which receives only a bare mention, is one of the most remarkable figures in Topsell, and he copied it from Gesner, who in his turn took it from Thevet of 1558. The description of this animal fits in with no known species, but it cannot be doubted that the figure was inspired by the sight of an American opossum carrying its young on its back. P. 221: The history of Dürer's rhinoceros in zoological literature is curiously relevant to the soundness of Dr. Raven's theme. P. 230: The commonly accepted biographical details relating to Leonard Mascall were shown to be inaccurate by Sir Frederick Smith in 1919. Nothing certain is known of Mascall's career. P. 235 *passim* and index: Jan Jonston's name is wrongly spelt. P. 337: The inexact quotation from Sir Thomas Browne is apparently taken from Wilkin, who was not always an accurate transcriber of Browne's manuscript, and "Turn" was understood to be Turner by Southwell in 1902. F. J. Cole

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MEN OF SCIENCE IN INDUSTRY AND SOCIETY

The Engineer in Society

By John Mills. Pp. xix+196. (New York: D. Van Nostrand Co., Inc.; London: Macmillan and Co., Ltd., 1946.) 14*s*. net.

THE right relation of knowledge and power—the means by which we can best secure that action in political and social no less than in industrial problems is determined after full regard to the scientific and technical factors as well as to the other elements in a situation—remains one of the central problems of our time. There are signs that appreciation of the importance of this problem has led to new attempts to find a solution. These attempts have clearly been on three lines: the provision of more effective administrative organisation by which the scientific worker can make his contribution; improvement of the training of the administrator; and the improvement of the training of the scientific man; while it has not been altogether overlooked that in a democracy the education of the ordinary citizen himself is also an important factor.

Mr. Mills in this book addresses himself squarely to the question why the scientific man, and more especially the engineer, does not occupy in society the position which his technical achievements and the part they have played in the radical transformation of the conditions of living would seem to warrant. He seeks to lay bare the reasons for his failure to do so, and to indicate by what steps he can take a more effective place in the control of the forces which his discoveries and inventions have released. But once again we find the physician surer at diagnosis than at prescription, and while there is much sound advice to the young industrial scientific worker, albeit frequently couched in jargon, or at least rather uncouth writing, Mr. Mills' contribution to the fundamental problem of how the man of science is to take a more effective place in the life of society is slight indeed. In that Mr. Mills concludes with half a dozen chapters on exposition in which the first essential to persuasive writing—clear thinking—is well brought out, and one chapter on "Reader Consciousness" indicates that Mr. Mills, at least in theory, is alive to the importance in either spoken or written exposition of considering first the needs and limitations of the audience or reader, he is at least open to the indictment that his practice is rather short of the standards he holds out for attainment.

What Mr. Mills has really given us in this book is something in the lineage of Samuel Smiles and "Sanford and Merton". It is a cautionary book for the scientific man or engineer contemplating or embarking on an industrial career. It abounds in suggestions, but few are pursued to any length; and indeed it is so discursive that adequate treatment of the themes raised would have made the book intolerably long, even had many of the irrelevancies been rigorously pruned. The author has something to say about the qualities which should determine the choice of research appointments as well as about the selection of men for the research—and the social waste when scientific talent of conspicuous ability is drawn off into administrative positions as soon as its full powers in research have been developed. On motives, incentives and salaries he is refreshingly forthright, sometimes provocative but usually stimulating, as further exemplified in some remarks on creative thinking in a chapter "The Art of Thought".

Mr. Mills comes nearest to his title theme in writing of professional associations, and his comments on the characteristic weaknesses of such bodies are just as pertinent to British organisations as to their American opposites. Nevertheless, he believes that scientific workers in industry should organise for their own protection and advancement, but even more for the great opportunities of social service which such organisation makes possible. In urging this he points out that this does not mean that scientific workers should be organised: his comment elsewhere on the tendency in present industrial conditions for the creative scientific man to lose his professional attitude deserves to be pondered when we are reviewing our whole organisation for scientific and industrial research. The problem which such professional bodies should examine is an engineering study of their class relationship to society. Commencing with a study of remuneration and of other incentives, he suggests that such a study might lead

to others which will bring the engineer and scientific man into fruitful contact with the major problems of our time. If the project is attacked objectively by the scientific method, it should lead to results of social importance; and the core of the book really lies in Mr. Mills' plea for all scientific men of good will to join in an intelligent attack upon the social, economic and political problems of the day by an evolutionary application of the methods of science. Primarily that means a study of the problems of organisation, for the scientific method is to-day so little employed outside physical problems and, as Mr. Mills shows, is so diametrically opposed to the interests of particular classes, that its use in open attack may be impracticable. None the less, he believes its use is the last hope of our civilization, and his dignified plea for the engineer and scientific man to apply the objective method of science to the things directly affecting their lives and national surroundings without regard to inbred or subjective attitudes goes far to redeem his blemishes of style.

R. BRIGHTMAN

WIRELESS DIRECTION FINDING

Wireless Direction Finding

By R. Keen. Fourth edition. Pp. xii+1059. (London: Iliffe and Sons, Ltd., 1947.) 45*s*. net.

THE appearance of the fourth edition of this book will do much to dispel the impression, prevalent in some quarters, that the technique of radio direction finding has been rendered obsolete by the introduction and development of radar in recent years. As the author explains in his introductory chapter, there are several fields in which direction finding will still have commitments for many years to come. The relative simplicity of the equipment required to give guidance to ships and aircraft, and particularly to those in distress, makes it an invaluable aid to navigation; in another field, the network of direction finders provides the only means so far available of locating radio transmitting stations, and such information is frequently required under peace-time conditions as well as in time of war.

In spite of the fact that the present book excludes a discussion of radar technique as such, it is a considerable enlargement on the previous edition, which was reprinted four times during the War. The only new chapter added describes the recently developed radio navigation systems such as 'Gee', 'Loran', 'Decca' and 'Consol', some of which use pulse modulation and some continuous-wave technique. The remaining chapters have been suitably expanded to include material descriptive of advances and developments; much of this material has only recently become available for publication.

Two of the most important additions are the sections on the calibration of direction-finding systems of various types, and on the classification of observed bearings. On both these subjects there has been much confused thinking in the past, and their detailed study has resulted in considerable improvement in the accuracy with which radio bearings can be observed and interpreted. The subject of radio wave propagation at both high and very high frequencies is treated somewhat more fully, since a detailed knowledge of this is fundamental to the successful exploitation of direction finding.

The book has been brought up to date also by the addition of details of new equipment developed both in Great Britain and in the United States, and including blind approach and landing systems for aircraft, improved forms of the Adcock and spaced-loop aerial systems, and various types of cathode-ray tube presentation devices. The bibliography is, as in previous editions, an important feature of this book. With more than four hundred references, it forms a very useful guide to the literature of the subject, and it includes the titles of some papers still in course of publication.

As a comprehensive, practical manual on the various aspects of radio direction finding, the book can still be confidently recommended to students, engineers and other workers in this field.

R. L. SMITH-ROSE

NEWTON TERCENTENARY CELEBRATIONS

Royal Society

Newton Tercentenary Celebrations, 15–19 July 1946. Pp. xv+92+6 plates. (Cambridge: At the University Press, 1947.) 10*s*. 6*d*. net.

THE tercentenary of the birth of Sir Isaac Newton occurred in 1943. The Royal Society arranged at that time a commemorative meeting, and it was decided that more complete celebrations of an international character should be held after the War. These celebrations were held in July 1946, and invitations to send delegates were extended to the national academies of the world; in spite of the difficulties of travel, more than thirty countries were represented.

During the course of the commemorations, a number of addresses on various aspects of Newton's life and work were given, which were of considerable interest. These are all printed in the present volume, together with the list of delegates and the programme of the celebrations. It is well that they should be published in this way and so made available to a larger audience. The principal address, on "Newton", by Prof. E. N. da C. Andrade, gave a brilliant account of the life and achievements of Newton; in a very effective manner he called on the great men of science, from Newton's to the present time, to pay their tributes to Newton's genius. Among the other addresses of special interest were those on "Newton and the Atomic Theory" by Academician Vavilov; on "Newton: the Algebraist and Geometer", by Prof. H. W. Turnbull; and on "Newton, the Man", by the late Lord Keynes, which was read by his brother, Mr. Geoffrey Keynes.

At the opening address to the delegates, the president of the Royal Society announced that the Chancellor of the Exchequer had agreed to ask Parliament to vote a sum of money sufficient to provide an Isaac Newton Observatory, to house a reflector of 100-in. diameter, as a fitting national memorial to commemorate the tercentenary of the birth of the greatest British man of science. The design of this telescope is now under consideration by a special board of management which has been constituted.

The volume is illustrated with three portraits of Newton, an old engraving showing Newton's rooms at Trinity College, Cambridge, a drawing of Woolsthorpe Manor by Mr. Hanslip Fletcher, and a reproduction of a letter from Newton to Halley.

Plato's Theory of Education

By Prof. R. C. Lodge. With an Appendix on The Education of Women According to Plato, by Rabbi Solomon Frank. (International Library of Sociology and Social Reconstruction.) Pp. viii+322. (London: Kegan Paul and Co., Ltd., 1947.) 18*s*. net.

THE aim of this important book, by Prof. R. C. Lodge, of the University of Manitoba, is to meet the needs of students of educational theory, "of those who are interested in Plato as thinker and who find in him a standing challenge to their own powers of thought, and of that wider group who are seeking to enlarge their own vision". The author considers Plato as writer, teacher, and thinker who believed that in the balanced philosophic life is to be found the solution of all human problems. Prof. Lodge fulfils his promise in twelve admirably written chapters. Turn where you will in these chapters, and you are struck by their freshness, clearness and vitality. He writes as a scholar, but not for scholars only.

As to the bibliography, a British reader naturally expects to find certain names, and he does find the names of Nettleship and A. E. Taylor. But he wonders why no mention is made of Bernard Bosanquet, the distinguished author of "A Companion to Plato's Republic" and of "The Education of the Young in the Republic of Plato", published in 1900. There was good reason for omitting R. H. S. Crossman's "Plato Today" (1937), which is too exclusively British in its outlook to attract an American writer. Some of the British books mentioned by Prof. Lodge, though important in their own way, contain only bare references to Plato. For this there may be good reasons; but their inclusion looks rather odd.

Mechanics

By Prof. John C. Slater and Prof. Nathaniel H. Frank. (International Series in Pure and Applied Physics.) Pp. xiii + 297. (New York and London: McGraw-Hill Book Co., Inc., 1947.) 20*s*.

THE word 'mechanics', although derived from μηχανη, a machine or contrivance, is often used to describe the general treatment of natural philosophy by mathematical methods, and it is in this sense that the authors here employ it. This particular work is the first of several, which are intended to replace their "Introduction to Theoretical Physics", published in 1933, and is presumably to be followed by others on electromagnetism and quantum theory. In this dissection, it is believed that a better treatment of each field can be provided, at the same time preserving the general unity essential both to teacher and student.

The main emphasis here is on dynamics and the theory of vibrations, and the first seven chapters are devoted to the classical development of this theory. After the enunciation of Newton's laws of motion the fundamental principles of particle and rigid dynamics are deduced, to be followed by the methods of Euler, Lagrange and, finally, Hamilton. Special vibration problems are then considered, such as those of a string, a membrane, and an elastic solid, and the last chapter is concerned with the elements of irrotational fluid flow. A number of appendixes are also provided to elucidate the properties of complex numbers, vectors, tensors, Fourier series and Bessel functions, which have been previously utilized in the main text.

The whole work is beautifully bound and clearly printed on good quality paper, and should prove a useful book of reference. J. H. PEARCE

Die Bluteiweisskörper des Menschen

Untersuchungsmethoden und deren klinisch-praktische Bedeutung. Von Dr. F. Wuhrmann und Dr. Ch. Wunderly. Pp. 354. (Basel: Benno Schwabe und Co., 1947.) 36 Swiss francs.

THIS book is divided into three parts, of which the first deals with the general physico-chemical properties of serum proteins. The second chapter considers methods used in the study of serum proteins: electrophoresis, ultracentrifugation, colour tests such as the Millon reaction, and finally a series of empirical clinical methods such as the Takata reaction, among them some not in use in Britain. In the third part an account is given of the changes occurring in diseases as revealed by the methods described previously. The fourth chapter groups diseases according to the serum fraction mainly affected by them. The concluding chapters sketch the formation of blood proteins (13 pages) and the therapeutic application of serum fractions (17 pages).

A work such as this, written by five authors, will necessarily show some unevenness; but by more severe editing, some repetitions might have been prevented. In the pathological sections, English literature is not sufficiently taken into account. In the chapter on nephrosis, for example (p. 281), out of fifty references, only one is to an American publication, and there is not one to a British journal. In spite of these shortcomings, the book contains much valuable information and will enable workers in this field to get an insight into the trends of research in Switzerland.

Recent Advances in Endocrinology

By Prof. A. T. Cameron. Sixth edition. Pp. vii+443. (London: J. and A. Churchill, Ltd., 1947.) 21*s*.

IN form, this sixth edition does not differ from its predecessor, which was published in 1945, and the revisions it incorporates are in general only slight. The more important additions are paragraphs on the treatment of hyperthyroidism with thiouracil, and on the iodoproteins; further information about the effects of adrenalectomy and the treatment of Addison's disease; and some interesting new facts about the parathyroids. The book is a very useful summary of the whole field of hormone studies, and it is bound to enjoy the success of previous editions.

Exploring Our National Parks and Monuments

By Devereux Butcher. (Published under the auspices of the National Parks Association.) Pp. 160. (New York and London: Oxford University Press, 1947.) 15*s*. net.

THE United States have long given a lead to the world in the matter of national parks. Although the Yellowstone Park is world-famous, it is but one of their many Nature reserves, embracing some twelve million acres of land, lake and forest. There are reserves from Maine to California and from Alaska to Florida. This book by the executive secretary and editor of the National Parks Association of America is a guide to their twenty-four national parks and thirty-eight Nature monuments. It gives a description of each reserve, its scenery and fauna; also how to reach it and the accommodation available for visitors. The many photographic illustrations are excellent and more than tantalizing for the English reader, whose travel opportunities are now so restricted. The book is well produced and admirably fulfils its object. FRANCES PITT

OPERATIONAL RESEARCH

By Sir CHARLES GOODEVE, O.B.E., F.R.S.

DEFINITION AND USE IN WAR

THE term 'operational research' came into prominence during the War to describe what to the Services was a new type of thinking process used to arrive at answers to questions arising out of the operations of war. This thinking process has, however, already to some extent been used in industry under other names. It has been applied to market problems, cost accounting, quality control and works efficiency; in other words, to the operations of industry[1]. It has also been applied to agriculture and medicine. Its successful application during the War is already stimulating and extending its peace-time application.

Operational research has been defined in various ways. I commonly call it "quantitative commonsense"; but more specifically, *operational research is a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control.* This definition is based on that put forward by Kittel[2] and is preferable to the more complicated and limited one put forward by Watson-Watt[3]. According to the scientific method reliance is placed only on controlled experiments or on experiences, the observations of which can be analysed. From the analysis, conclusions are deduced, using the rigorous logic of mathematics and statistics.

The applied nature of operational research is shown by its association with executive decisions, and it follows that workers in this field must be closely in touch with, if not part of, executive departments.

The field of operational research depends on the interpretation of the word 'operations' in the definition. This paper attempts such an interpretation by means of illustrations. In war, operational research was applied to the use of weapons, to tactics, and to strategy. In the peace-time application of operational research, studies are directed, for example, to the use of equipment and man-power, to operating procedures, and to the solution of those many problems faced by management in operating or controlling factories or public utilities, or by Government authorities in planning. The field of operational research is very wide; but it will be seen that it is quite distinct from the field of most applied scientific research, the latter being concerned with new or improved processes, equipment, materials, etc.

Let us first look at some of the examples from the Second World War. Operational research was really born out of the 'Battle of Britain'. As is well known, we had in 1940 relatively few fighter aircraft compared with the number that would have been required to defend our shores against an air invader. We had very good fighter pilots and very good aircraft; but, with the equipment and methods used prior to 1940, it would have been impossible to obtain sufficient interceptions to defend our shores. The most important new feature that came in was, of course, radar. This equipment, by giving ample warning, permitted the retention of aircraft on the ground until needed, and then, by plotting the positions of the enemy and defending aircraft, enabled a 'ground control' to direct the aircraft to a position where the enemy could be sighted visually. The planning of this sequence of operations involved careful analysis of training and of operational experiences, and involved also a full analysis of the technical possibilities of the equipment. But the process of combining these factors required mathematical calculations beyond the experiences of the ordinary commanding officer. Accordingly, a small party of half a dozen scientists was attached to Fighter Command, to study and refine the deployment and the operational orders. These scientists learnt how to estimate which were the bad targets and which were the good, and to determine where and how our limited effort could best be expended. Their analyses formed the basis for the operation of the whole defence organisation of Britain. It is estimated that radar itself increased the probability of interception by a factor of about 10; but that, in addition, this small operational research team increased the probability by a further factor of about 2, which together meant that the Air Force was made twenty times more powerful. The operational research contribution, a doubling, was out of all proportion to the amount of effort spent on the research.

An even more startling case was the introduction of Coastal Command to the Battle of the Atlantic. While Coastal Command had a number of successes in the early days of the War, these fell far short of what was needed when the U-boat campaign was renewed with increased intensity during the winter of 1941–42. Prof. P. M. S. Blackett[4], whose name will go down in the history of operational research as outstanding, came into the picture to see what could be done. He built up a small team of scientists at Coastal Command to study all aspects of the problem of air attack on U-boats. Of particular importance was the work of the late Prof. E. J. Williams, who, in the spring of 1941, analysed the previous attacks on U-boats by Coastal Command aircraft. This analysis led to the conclusion that, instead of the depth-charges or bombs being dropped more or less on and about the centre of the targets, there was a serious and not obvious fault in the tactics adopted. Indeed, it later came out that the chances of a successful kill were something like one in a thousand.

The tactics accepted at that time were based on a belief that the best setting for a depth-charge to explode was 100 ft., where the charge would be well 'tamped' by the water. It was also known that when a U-boat dived, it increased its depth at the rate of about 2 ft. a second, and that accordingly it should have been submerged for at least 40 sec. before the depth-charge exploded. (The lethal range of a depth-charge is about 20 ft.) Allowing for the speed of descent of the depth-charge and the forward movement of the submarine, the best time and place to drop the depth-charge could be calculated, using as a point of reference the swirl left by the submerging U-boat. To carry out the attack properly, it would commonly be necessary for the aircraft to frighten the U-boat into submerging and then attack at the appropriate number of seconds later. (In fact, of course, most aircraft went straight into the attack.)

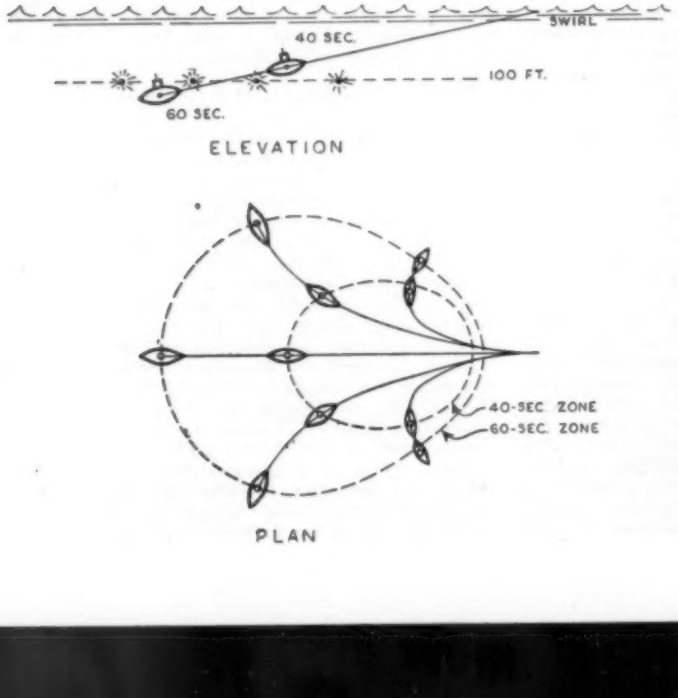
Prof. Williams' analysis showed, among other things, the following statistics (see ref. 4) for the number of U-boats visible and having submerged for different times at the moment of attack:

Condition of U-boat	Percentage of all attacks
U-boats visible	34
Submerged up to 15 sec.	27
,, 15 to 30 ,,	15
,, 30 to 60 ,,	12
,, more than 60 sec.	11

From this it is seen that only about one-tenth of the U-boats could be in the depth-range of the exploding depth-charge, when set to explode at 100 ft. The analysis further showed that the volume of the 'probability zone' in which the submarine lay increased very rapidly, indeed, according to the third or fourth power, with the time of submergence. (See accompanying diagram.) This three-dimensional probability zone is that inside which it is almost certain (that is, 97 per cent probable) that the submarine will be found and is calculated by allowing for all possible movements of the submarine inside the limits of its estimated course and speed, turning circle, etc. The inaccuracy with which the depth-charges were dropped also increased very rapidly with the time of submergence, largely due to the disappearance of the swirl. Taking the two together, it was found that, of the one-tenth of the U-boats which were within the lethal range for depth, fewer than one in a hundred were within the lethal range for plan. By setting our depth-charges at 100 ft. we were failing to engage the targets which could be attacked most accurately and which were by far the most frequent, that is, U-boats visible or submerged up to 15 sec., simply to gain the small increase in lethal range of a depth-charge at 100 ft. This is probably as serious an example as we could have of the concentration on bad targets and the disregarding of good. It is difficult to appreciate how it can have arisen until one realizes how ingrained and over-emphasized certain technical facts on underwater explosions had become. In fact, the change to the shallowest possible depth setting was opposed by a number of technical people, until they were shown the full analysis giving the other aspects of the problem. (This case also showed up a good lesson in research management. In accordance with the procedure at that time still prevailing in this section of the Admiralty organisation, orders were passed to the research station concerned to make the necessary alterations in design. The delay which followed led to a visit of inquiry which elucidated the situation described above. When the research people concerned were finally convinced, the 'unsurmountable' difficulties were resolved in a week.)

To conclude this story, within a very short time of the change being made, first to 35 ft. and later to 20 ft. depth setting, one U-boat was sunk and another captured and brought into port, the only enemy submarine captured during the War. The sinkings went up steadily until a year later they reached twenty a month. The Germans within the first month announced to their Navy that we had introduced a new and much more powerful depth-charge. This change brought Coastal Command effectively into the War, and their aircraft, together with the sea-borne forces, with which they were closely integrated, averted defeat in the most critical period of the U-boat war.

My third story has a somewhat amusing side. During the latter phase of the U-boat war, the enemy U-boats in the Bay of Biscay were countering our radar with some success by listening to the transmissions from our aircraft, and diving at the appropriate moment before we could pick up the radar echo. We countered this by special technical devices and managed to maintain a certain low rate of successes against the enemy. The operational research team of Coastal Command showed, by careful statistical analysis followed by model exercises on a games board, that a saturation technique was possible which would take advantage of the fact that the U-boats' storage batteries would not permit submergence for more than four hours, during which time they would move a certain maximum distance. With the required number of aircraft working in accordance with a definite plan of patrol, there would always be an aircraft inside the critical listening range when the U-boat surfaced, and the latter would be forced to submerge before it could properly recharge its batteries. We would thus exhaust our opponent and he would be forced to stay on the surface. Our sightings would increase to about twenty per week, and as we were getting about one kill in every ten sightings, this would mean about two kills a week. The required number of aircraft was twenty-five more than were available for this patrol force, and a considerable argument with Bomber Command followed a request for the additional aircraft. In this argument, a senior Bomber Command officer inquired whether this War was to be fought with slide-rules or weapons. However, a three weeks trial of the full operation was ordered by the Prime Minister, resulting in sixty-seven sightings and six kills. An extraordinary coincidence perhaps; but the 'slide-rule' had won!



METHODS OF OPERATIONAL RESEARCH

Statistical Analysis

The foregoing examples are obviously very important ones, but they are rather too complex to illustrate methods of operational research. For this purpose a different approach is necessary. In most problems, there are a number of variables to be considered. Our first object is to find the correlation between these variables, our second to test the stability of this correlation by finding the causal link lying behind it, and our final object is to estimate the likely consequences of any particular change that may be imposed upon the system. We thus provide ourselves with a quantitative basis for any decision to be made regarding the change. For example, how does the number of ships sunk in a convoy depend upon the speed of the convoy? Is the speed the direct cause of the effect? How many ships are likely to be saved if the speed is increased? What will be the cost resulting from the elimination or re-routeing of slow ships, etc.?

Unfortunately, most problems have many variables, which are varying in apparently quite unco-ordinated ways. In addition, there are often superimposed completely random fluctuations, which tend to obscure the correlations. One generally attacks a problem first by a study of past experiences; if one is lucky, it might be possible later to organise an experiment to test some particular point. The data from these experiences are subjected to a statistical analysis to determine the *intensity* of the correlation between any pair of variables. Are the higher sinkings more frequently found to occur with slow speeds of convoys than with fast? (The answer, during the War, was found to be 'Yes'.) The intensity of this correlation is expressed quantitatively by the 'correlation coefficient' determined from the statistical analysis.

If a correlation is found, the next step is to find the form of the relation between the two variables. Statisticians call this the 'regression' of one variable on the other. More specifically here we want to know the partial differential coefficient relating the change in sinkings to a change in speed, the other factors, such as size of convoy, air and sea protection, route, etc., being constant or accounted for.

The causal link is best determined from theoretical or other independent grounds. The speed of the convoy is clearly an independent variable, but it may be that the correlated rate of sinkings really depends on some other variable itself accidentally intensely correlated to the speed. For example, the ships might make smoke when steaming at slower speeds and thus be detected by a U-boat at a longer range. However, a study of the performance of the enemy's submarines and of his tactics showed clearly a direct causal link. It was possible to go further and predict approximately the relation between sinkings and speed, and this relation was found to agree satisfactorily with the operational data. It could, therefore, be predicted that, if it was decided to make a certain increase in the speed of convoys, a certain increased safety was to be expected. The loss due to various dislocations of convoy routine was separately calculated and set against the gain, and the net result formed the basis for decisions to increase speed in many important convoys.

Models and Experiments

As will be seen from many of the examples in this article, one of the commonest methods of operational research involves setting up one or more possible imaginary models, studying their expected characteristics and seeing which fits the data best. This is exactly the technique used in the determination of crystal structure by means of X-rays. It is impossible to deduce the structure from the data on X-ray diffraction—the mathematical equations cannot be solved in that direction. One can, however, very accurately calculate the diffraction angles and intensities for a given model or series of models derived from other considerations and be satisfied that only the correct model will lead to data which fit the observations.

Similarly, one can make use of analogies, particularly electrical analogies, as is done so commonly in various branches of physics and engineering.

The use of direct experiments to test a particular point is, needless to say, of the greatest value, but experiments often involve considerable cost. As operational research becomes more accepted, experimental operations will become more common, which in turn will add to the strength of this branch of science.

Sampling and Significance

Full technical details of this important subject can be found in standard text-books such as that by Davies[6]. The relative advantages and weaknesses of different methods of sampling are well known and the reliability or significance of a conclusion from a particular group of data can be determined by standard statistical methods. If certain returns show variations from week to week, a statistical analysis can show what is the chance that differences, equal to or greater than those actually observed, could have arisen from random fluctuations. If the odds against are high, it can reasonably be assumed that some extraneous factor is present; highest odds being necessary where a wrong decision would involve serious consequences.

The significance of a conclusion is greater (that is, the odds are higher) the greater the number of data in relation to the number of variables. The experiences of the War, however, have shown that one should not be deterred from attacking a problem even with only very limited data, particularly when the problem is an urgent one; that is, the risks of delay may be greater than the risk of a decision based on low significance. Very often parts of the picture can be filled in by theoretical deductions and thus one might narrow down the apparent fluctuations and thus effectively increase the significance. In this way, operational research or applied statistics, whichever one cares to call it, departs from or goes beyond the more rigid field of pure statistics.

For example, supposing that over a period of time and in a given area or business there is an average of 500 events per week. If each one of these events were completely independent of one another and of any common factor (that is, they occurred at random, such as is nearly the case with births, accidents, placing of orders, etc), then the odds are fifty-fifty that any particular week would show less than 485 or more than 515 events. In other words, if a week showed, say, 484 events, it does not really mean that the 'orders have fallen' or the 'accidents have fallen', as one commonly sees reported. It *may* be true, but

no decision should be based in any way on an isolated fact of this kind.

On the other hand, in a case where the events are the completion of operations in a production line, and where the time of beginning one operation depends primarily only on the end of the previous operation, a weekly return of less than 485 events would be of great significance and extraneous factors should be sought. The significance, therefore, depends not only on the statistical data, size of sample, etc., but also on the expectations of the 'standard deviation' based on an analysis of the technical characteristics of the processes involved.

This question of significance of observations is one of the most important to executive decisions. Probably more wrong decisions arise from an over-emphasis being placed on chance happenings than from any other cause.

Soundness of Data

Before going on to further methods of operational research, some remarks on data are necessary. It is obvious that the soundness of data should be thoroughly tested before the data are used. Hearsay evidence is extremely dangerous. Two examples will illustrate the mistakes that might arise.

In 1940, we were asked at the Admiralty to redesign a certain weapon to enable it to fire vertically. When interrogated, crews of ships attacked by enemy dive-bombers were almost unanimous in saying that the dive-bombers came down vertically. By placing an inconspicuous grid on the wall of the interrogation room and asking the witness to point his hand in the direction of the aircraft, it was soon found that 'vertical' to a man being attacked was between 45° and 75°. This research saved us the task of overcoming very difficult design problems to produce a weapon which would have been of little value.

A similar incident took place with regard to the depth setting of ship-borne depth-charges. Reports from ships at sea continually stated that the enemy submarines went deep and below the deepest setting on the depth-charge. In fact, figures were quoted to support the claim. The statement was suspect because there is a natural tendency in a man, who has carried out an attack accurately so far as he can see, to blame the one factor he could not control, in this case the depth below the deepest setting. Fortunately, it was possible to get an approximate idea of the depth of the enemy submarine by the range at which the asdic beam lost contact, the angle of the lower edge of the beam being known very approximately. This gave a fairly reliable knowledge of the depths of submarines during attacks and showed that very few, if any, were going anywhere near the depths alleged.

The remainder of this story tells of a failure to apply operational research results. The myth that enemy submarines went deep, based at first on human weakness but kept up by intelligence reports from German sources, resulted in an extensive wastage of depth-charges and the escape of many German submarines.

Probability Calculations

The example of the gun just quoted is an interesting one to illustrate a common type of problem. A gun with its sights can be designed to be at its best at a certain angle of fire, its effectiveness falling away on either side of this angle. The usual requirements ask for a gun to have the maximum probability of shooting down enemy aircraft and at the same time to be able to engage an aircraft no matter at what angle it may be. A study of this problem shows that the two requirements are conflicting, and one must choose between the two or compromise. From an analysis of attacks carried out both by enemy aircraft and our own, it was fairly easy to determine the approximate shape of the curve relating the probability, $Q_t d\alpha$, of finding a target at a given angle α (that is, between α and $\alpha + d\alpha$) above the horizontal as a function of that angle. In a similar way, one can determine the probability of hitting, P_h, as a function of the angle. One can determine the overall probability by integrating the product :

$$P = \int_{\alpha}^{\pi/2} Q_t P_h d\alpha.$$

The integral will have its highest value under the conditions where the highest values of P_h coincide with the highest values of Q_t ; the contribution to the integral of a region where P_h might be high and Q_t low would be negligible. In other words, the gun should be designed to be most effective at those angles where targets are most probably to be found, and other angles should take second place or be ignored. In this example, Q_t is very low at 90° elevation and so, indeed, in almost any design of gun, is P_h. The complications of designing to cover 90° elevation, particularly as this would lead to reduced effectiveness of the gun at other angles, would reduce the value of the weapon. (In this example, the effects of range; enemy speed, etc., would be roughly included in Q_t and P_h, but in more precise work double or triple integration would be required.)

This is a common problem where coincidences are required. In general, where the requirement is to get the maximum number of hits, we want the integral of the products of the various probabilities to be a maximum, and for this we want the maximum amount of overlapping of the probability curves. We have already seen an important but more complicated example, that of depth-charges used by Coastal Command aircraft. Here, however, the mathematics by the integration method would be too complex and it is necessary to use more approximate methods, in which the submarine is assumed to lie with uniform probability inside a circular or oval-shaped zone. The size of the zone is, of course, a marked function of time ; if it is a three-dimensional zone its volume may go up as the fourth or fifth power of the time.

A further example of this type was found in the case of Coastal Forces' counter-attacks on raiding enemy E-boats. The E-boats were first spotted and plotted by radar and the motor gun boats were sent out to attack. As in the case of Fighter Command, the gun-boats were controlled as near as possible to the position of the enemy and if a sighting occurred the enemy was attacked. Most of the E-boat sorties took place in weather of low visibility, which, of course, made our counter-offensive much more difficult.

There was, however, a marked difference between the percentages of sightings obtained by the flotillas of two separate Commands, and a study was made by the naval officers concerned to find the cause. It was appreciated that up-to-the-minute information was important, but it was found that the average

time between the obtaining of the position of the enemy and the passing and re-plotting of this position on the charts of the gun-boat was the same for the two Commands. In other words, there appeared to be no statistical difference between the times of the two flotillas. However, the average taken was a linear average, whereas the probability of interception is a function of the inverse third or fourth power of the time. Therefore, the average taken should have been of the times raised to the third or fourth power rather than to the first. When this was done, there was a marked difference found in the averages of the two flotillas, quite sufficient to account for the difference in success.

In other words, there were big fluctuations in the times of transmission. In the successful flotilla, there were fortunately quite frequently a number of short times of transmission and these were responsible for most of the interceptions. In the other flotilla, while the average time was the same, there were fewer exceptionally short times. This fact was not obvious in view of the large random factor involved in the interception problems.

These are examples in which common sense, by applying the scientific method, has been turned into quantitative common sense.

Causal Links

A discussion of causal links is liable to lead one into the realms of philosophy or at least into difficulties as to the meaning of cause and effect. However, there are many branches of science in which there is no ambiguity and in these one can predict with a high degree of certainty that if certain things are done, a known effect will follow; for example, a force can *cause* a movement. As one of the primary objects of operational research is to predict the future, it is necessary to find some assurance that a particular relation between two variables is a stable one. If the data go back some time and have consistently supported the relation, then stability can probably be safely assumed, but the best basis for security lies in an accurate knowledge of the causal link behind the empirical relation. With such a knowledge, it is possible to use data collected over a shorter time and to make all conclusions of much wider and more general application.

It has already been emphasized that statistical correlation between two variables gives no indication of a causal link. Indeed, the history of applied statistics is full of examples where inexperienced people have jumped to conclusions in this connexion. For example, during the War a graphical correlation between the numbers of pilots having various degrees of 'night vision' and the successes of pilots in intercepting enemy aircraft at night was taken to prove the importance of 'night vision' (the tests actually included intelligence and quickness of response as well). A closer scrutiny of the results, however, showed that the predominant factor was the distribution of pilots over the various degrees of night vision, and the coincidence of the maxima of the two curves at 'degree 22' merely showed that the successful night fighters had the same *average* night vision as the bulk of the pilots.

It is well accepted in the iron-making industry that the output of a blast furnace falls if the conditions are changed to produce iron with a higher silicon content. This, indeed, can be proved very clearly from statistical data. The real cause here, however, lies first in the fact that higher silicon iron requires a higher temperature to shift the equilibrium towards the reduction of silicon dioxide, and the blast furnace would require more coke and more air in relation to the iron produced. Blast furnaces are designed, however, to operate with a more or less fixed maximum quantity of air and, therefore, the output falls, simply because in practice the furnace cannot get more air. There is thus no direct causal link between output and silicon content. A furnace to give a fixed through-put of iron could be built, but it would require a different design.

Organisation of Operational Research

Operational research may be carried out in two ways: either as part of ordinary research work or in a separate section set up for the purpose. Each of these has its protagonists. Clearly, a man who undertakes the research and development leading to a new piece of equipment or a new process should learn for himself the many operational problems concerned therewith. He should also follow up his new equipment or process by studying its behaviour in actual use. This might or might not be called 'operational research' according to the use made of the methods outlined in this paper.

On the other hand, there are severe limitations on this latter type of organisation, limitations which can largely be overcome by the setting up of a separate section. If operational research is to provide executive departments or managers with a quantitative basis for decisions, the men carrying out the research must be in the closest possible contact with the men who make the decisions; the value of their advice will be directly related to the extent to which they can see the overall picture of the problem under consideration.

A second advantage of a separate section is that it frees the operational research workers from executive responsibility. They are thus able to initiate studies with greater freedom and are limited only by the confidence that can be built up between themselves and their colleagues. Executive responsibility, whether in a normal research department or in management, has not been found conducive to the best operational research, and most of the successes of this work have been associated with 'free lance' teams. On the other hand, operational research teams should, of course, have a good sense of responsibility towards their task and their employers; but, as 'common sense' is one of the first qualifications of an operational research worker, no difficulty should be found in practice. A full discussion of the organisation of operational research must, however, await further peace-time experience.

PRESENT AND FUTURE OF OPERATIONAL RESEARCH

Application to Traffic Problems

The extension of operational research in peace-time activities is already in full swing, particularly in certain specific branches. Some of the most interesting recent applications have been in the fields of railway and road traffic. Both fields give a promise of useful results on the application of the scientific method.

One of the principal railways of Britain, the former L.M.S., has set up a special research unit

attached to the operational side of the railway, and this unit has already completed thorough studies of some parts of the communications system, on which the effective running of a railway so much depends. These investigations have shown quantitatively where delays more commonly occur and have also predicted the likely improvement and saving that would result from certain possible changes in organisation and equipment. Those changes which show good returns are now being made. Needless to say, studies are also being made in the delays in the operation of the trains.

The road problem has two sides, the reduction of accidents and the improvement in flow. Losses due to accidents or delays on the roads to-day represent a serious loss to our national income or productivity. The Road Research Board of the Department of Scientific and Industrial Research has set up a strong team to study the problems involved. A wide range of the tools of modern science are at their disposal, a major one being the statistical method.

There are many problems in this field. For example, studies are being made of the factors affecting the usefulness of a typical road junction as controlled, say, by traffic lights. From a flow aspect, the main object is to get through the maximum number of vehicles and pedestrians with the shortest delay for each. From a road safety point of view, the object is to reduce the probability of an accident, and particularly of a serious accident, to the lowest possible value. These two objectives are to some extent conflicting, but the extent of the conflict may be very considerably reduced by studying all the factors associated with the junction and with its use. In other words, it should be possible to increase the flow-rate and reduce the danger of accidents at the same time. The way to do this can best be found by a close study of the operations of the various factors involved. A statistical study can be made of a number of road junctions of the same type and loading, etc., and because of the fact that the frequency of accidents at each junction is low. It is necessary to deduce the relation between any two parameters from first principles, testing these relations where possible against such reliable statistics as may exist. These first principles are derived from studies of human reaction time, of the braking and manœuvring power of vehicles, of the conditions of the surfaces and the lay-out of the roads, of the timing and other characteristics of controlling lights, etc. Studies of this kind have, indeed, gone on for many years. As a result, London, for example, has one of the most highly developed and successful traffic signalling systems in the world. However, the development of this system is far from complete, but having been carried so far, much more powerful methods are now required to make further progress.

Most of the data in this field of traffic flow and accidents have been collected from studies of daily operations, with their associated mixture of variables, or by taking advantage of some change brought about for other reasons. In this field, however, changes introduced primarily to help disentangle data, that is, 'experimental operations', hold out great promise and, indeed, are already being tried.

There is one general point of technique worth referring to in connexion with this field. For example, it may be required to test experimentally the effect on a dependent variable, such as traffic flow rate, of increasing a given parameter, such as the width of a road section. The cost of increasing the width experimentally would be prohibitive, but a good approximation to the value of the partial differential coefficient in the neighbourhood of that particular road width can sometimes be obtained by experimentally *decreasing* the width of that section. This technique is based solely on the assumption, frequently a reasonable one, that the curve showing the relation between the two variables is a smooth one. The function need not be linear, but there should be no marked discontinuity or excessive curvature in the region considered.

There are also similar traffic problems more directly in industry. For example, the cost of transporting the fuel and raw materials and the products of the furnaces in an iron and steel works amounts to a large item in the cost of steel. This arises not only from the direct cost of traffic but also from hold-ups of parts of the plant awaiting materials, etc., or from more subtle points such as the need for close schedules. A full operational research into the details of this problem is now being made as a necessary preliminary to the engineering lay-out and design problems involved in improvements.

Application to Productivity and Output

Time and motion studies of operators of machines or of workers making repetitive operations have for long been one of the main research methods of the production engineer and the 'industrial consultant'. This method is steadily being improved and strengthened, recently by the exchange of lessons between this and other methods of operational research.

Extensive studies of productivity and of its reciprocal, O.H.P. (operator hours per unit of production) have been made by Tippett[4]. The factors governing O.H.P. in the factories of the cotton industry have, to a large extent, been resolved from a mass of data collected over a number of years. Decisions concerned with productivity by the management of individual firms, or policy decisions by Government Departments, are generally made with the results of these studies as a basis.

Similar studies have also been made of the processes occurring in chemical plant; but it is doubtful whether this should be called 'operational research'. It is probably better to consider this work as part of the normal type of research required to develop or improve existing processes.

Application to Inspection and Maintenance

Inspection has long been a field for the successful application of statistics; 'quality control' is now accepted practice with many large manufacturers. As an interesting example of a rather special type, an inquiry has recently been made into the distribution of the inspection effort in a steel works. In accordance with common practice, the inspection was made on a certain finished article at the end of a series of operations starting with the raw steel billet. Rejects at this final stage were, however, costly and the question arose: Could the faults leading to rejects be reliably detected at an earlier stage? A close statistical analysis, coupled with certain trial runs, showed that this was possible for several of the major types of faults, and the cost of the rejects has now been reduced to less than half without in any way lowering the standard. Furthermore, it was found

possible to eliminate certain of the final inspection tests as they were now covered by the earlier tests, and hence the total inspection effort was not increased. The research here led to no new equipment or process, but merely to a re-deployment of inspection effort.

Good examples of operational research applied to maintenance problems in industry are not known to me and therefore I am tempted to return to one of the most striking examples of the War, the studies made by Dr. C. Gordon, in 1942–43, on the maintenance of aircraft, some details of which are given in "Science at War" (p. 104)[7]. These studies of the occurrence of faults in aircraft as a function of maintenance showed that it was possible to increase the flying hours at the expense of the hours an aircraft spent undergoing maintenance without any appreciable increase in the number of faults. As a result, the rigid schedules of maintenance were altered, with a very substantial increase in our fighting strength.

An obvious example where operational research is needed to-day lies in the maintenance of road traffic signals. It appears that the cost to the community of faulty signals and of maintenance is wrongly balanced. In the aircraft example, maintenance was overdone, whereas in this example, it appears to be underdone. It seems likely that operational research methods can be of great use to the maintenance engineer.

Application to Technical Progress

The change in public attitude to science in recent years has led to the question: Why is there such a long interval between the discovery of a new scientific fact and its application to the benefit of mankind? The answer to this would in itself require a lengthy research, but one factor is of obvious importance. A decision to try an idea out, when made reasonably, is based on a weighing of the pros and cons, many of which concern costs in money, coal or man-power. If it is not possible to weigh these sufficiently accurately to see which is the greater, a decision is naturally postponed or made on a 'hunch'. If operational research is successful in providing a quantitative basis for decisions, it should be able to shorten the interval between discovery and application.

There is, however, a danger here that operational research will be diverted to the routine task of 'vetting' inventions which arise through the initiative of individuals driven by parental interest. Operational research workers should be able to take a wider view of a problem, study its economics and its technicalities as a whole and, as a result, see how a proposed change or invention would affect the problem.

In certain research associations, such as that for iron and steel, operational research is already playing a major part in the formulation of programmes of applied or objective research by providing a logical basis for deciding what is worth while developing through its later stages.

Operational research is also playing a part in following up technical progress. The Ministry of Agriculture analyses regularly how far the knowledge of scientific research is being applied by farmers and thus obtains a basis for part of its educational and control schemes.

Future Trends

While there were certain technical developments in regard to the methods of operational research during the War, it is likely that these methods will be developed very much further. The application of the statistical tool is still on the increase, but there is no need or likelihood of the tool itself being developed further. There are many other tools in science, however, which will be tried, and some of which we hope will be successful.

One of the most important of these is the general concept of forces, potentials and equilibria in relation to the Second Law of Thermodynamics. This Law may be expressed in a general form as follows: If there is any 'tendency' for a certain thing to happen, or if a process is potentially able to take place in a certain direction, it should be possible to harness that process to produce external work, the amount of which per unit of process is a measure of the 'tendency'. In certain cases the tendency may be realized as a force.

The generalized Second Law of Thermodynamics should be capable of wider application despite the fact that one cannot take advantage of the rigorous relation between force and work found in the physical sciences. One of the most important forces in sociological systems is that of incentive. If an individual or a group of individuals does something in a certain direction, then there must be a force or incentive, the net value of which determines that direction. If we can elucidate and estimate the various components of that force, we can predict the behaviour of groups of people in given circumstances.

The concept of equilibrium is also capable of wide application, particularly as it can be shown that a system showing an equilibrium position can change only in a direction towards that equilibrium (except under external influence). Furthermore, the amount of the external influence required to keep a system away from its equilibrium rises rapidly with the extent to which it is kept away. For example, the cost of food subsidies rises rapidly as the equilibrium (free economic or supply-and-demand price) departs from the actual fixed price.

We can look forward to the day when the *science* of economics will be sufficiently developed to enable man to gain better control over his circumstances. I believe this science will only grow by the methods of operational research and more specifically by developing its own versions of the First and Second Laws of Thermodynamics, the First being the law of conservation of equivalence, the Second the law of direction of changes as governed by (economic) forces and of the associated conditions of equilibria.

Self-compensating and Self-aggravating Systems

This last point about equilibria leads to a further point. Practically all processes occurring in physical or natural science can be divided up into two categories, those which are self-compensating and those which are self-aggravating. The first are those described by the well-known theorem of Le Chatelier. 'If a change is imposed on a physical system in equilibrium, there are automatically generated other changes which tend to offset the effect of the first change.' This theorem follows from the Second Law of Thermodynamics and is of general application.

In contrast, self-aggravating systems are those in which a small change leads to a further change which *enhances* the effect. In the extreme cases, the result is catastrophic. In others, the enhancement proceeds

until other self-compensating or attenuating factors present bring the situation under control and possibly reverse the direction of the change. Such systems generally lead to vigorous oscillation.

There are many examples of each type of system in the ordinary operations concerned with our daily life. Of the first type, there is the example of the reduction of the blindness of a blind corner. Such a change should normally result in a reduction of the number of accidents at that corner, or at least the danger of an accident. As, however, it would be followed by an automatic increase in speed of the cars taking that corner (as a consequence of the greater security felt by the drivers), the net reduction of the danger will be less than would otherwise be expected. This simply means that danger and speed are in equilibrium.

A good example of the self-aggravating type concerns the movement of buses. Consider a system in which buses depart at regular two-minute intervals from a depot and pass along a route through a large town to another depot. Under normal loading and with no special obstacles, the two-minute interval can be retained fairly accurately throughout the entire schedule. If, however, a small delay takes place with one bus when the load is near the maximum designed value, this bus will then find itself faced with the problem of picking up a larger number of accumulated passengers than it would otherwise have had to do. This immediately adds further delays which further aggravate the loading on this particular bus. This, of course, is the basic cause of the 'convoys' of buses which form rather frequently in large towns such as London.

A very similar problem is found in connexion with the supply and demand of scarcity goods. On first thought, it might be assumed that a system, in which there was an even flow of cigarettes from the manufacturers to the shops and an even rate of smoking, would be one of stability. Indeed, in normal conditions when there is no thought of scarcity, it is. The stocks held in retailers' shops provide a reserve or buffer for fluctuations in demand. The ordinary person becomes used to the fact that he can buy cigarettes on demand and therefore it is not necessary for him to maintain a large stock of his own.

Under conditions of scarcity, however, the stocks of a retailer are considerably reduced and the stocks of the consumer are increased because of his bitter experiences in being refused. The situation fluctuates widely because should there be, by some initial fluctuation, a small deterioration in the supply position, a consumer's reaction is immediately further to build up his own stocks. This in turn aggravates the retailers' stock position and induces other consumers to take corresponding self-protective action. Thus a small decrease in the available supplies in shops can quickly lead to a complete emptying of the shops; a rumour can become a reality.

I once had the opportunity of studying a similar self-contained system. The supply of chemical apparatus from a college 'loan store' would collapse annually at a certain time due to a self-aggravating factor of this type. The collapse was preceded by a sudden falling off of returns of apparatus after use, the falling off in turn being due to the beginnings of non-availability of certain items. There are numerous other examples, such as a run on a bank or the locking of a traffic roundabout due to some small initial fluctuation when it is near its maximum loading point. The economic trade cycles are presumably kept in oscillation by self-aggravating factors of this type.

The method of combating self-aggravating systems by the damping effects of controls and reserves is also well known. This method is parallel to the use of resistances and condensers in electric circuits. Operational research can lead to more exact knowledge of these systems to enable a better balance between reserves and flow and a better phasing or timing of actions intended to damp down or offset an impending change. One of the greatest problems for the Government administration has been to obtain 'early warning' of a particular situation and thus to avoid the more drastic compensating action required if the problem is left until it has built itself up to a serious state.

Conclusion

The arguments in this paper are based partly on the experiences of War and partly on those of two and a half years of peace. There are obviously many differences between the two conditions. War leads to a great degree of centralization of control and consequently a lack of flexibility. This is a situation in which operational research is potentially able to produce enormous improvements, partly because in certain respects it is a situation full of weaknesses to start with. On the other hand, an industry consists of a number of units or firms each evolving its own methods and working independently. Accordingly, variations of working methods occur, if only by chance. In normal economic conditions, the variations of positive value will have a greater chance of survival than those of negative value. In other words, 'natural selection' can operate in the uncentralized systems, providing there is a freely competitive economic system operating. As a result, it might be argued that operational research would be less likely to make such startling improvements in peace as it did in war. However, the same is true for applied science in general: the results in war are much more startling than in peace-time.

History has shown that results in war are followed by extended application in peace-time, and the case of operational research is so far no exception. This technique is becoming a new tool for executives, alongside their older tool, accountancy. It is a tool that the executive man can readily understand; it is not wrapt in the 'mysteries of science'. For him, his business life is becoming more and more complex as the repercussions of any one act or decision become wider. As a result, the waste of time in arguing with 'half-truths' becomes more serious. We are entering an age of statistics collected with great consumption of man-power. The new methods of operational research are needed if these statistics are not simply to add to the half-truths but to play their proper part in the more highly developed thinking processes now required.

[1] See, for example, Pickard, R. H., *J. Roy. Stat. Soc.*, Supplement 1934.

[2] Kittel, Charles, *Sciences*, **105** (Feb. 7, 1947).

[3] *Nature*, **160**, 660 (1947). Summary of a discussion held by the British Association.

[4] The first general paper on this subject, entitled "The Methodology of Operational Research", was prepared by Blackett in 1943 and has been distributed privately since then.

[5] Davies, Owen L., "Statistical Methods in Research and Production" (Messrs. Oliver and Boyd, 1947).

[6] Tippett, L. H. C., British Cotton Industry Research Association, Shirley Institute Bulletin (1947).

[7] Crowther, J. G., and Whiddington, R., "Science at War". Pp. vi+185+51 plates. (London: H.M. Stationery Office, 1948.) 2s. 6d. net.

PROGRESS OF CANCER RESEARCH

By Dr. I. HIEGER
Chester Beatty Research Institute, Royal Cancer Hospital, London

THE composition of the twenty-fourth annual report of the British Empire Cancer Campaign (11 Grosvenor Crescent, London, S.W.1) shows that more research is being carried out on radiation therapy and theory, on carcinogenesis and on the biochemistry of cancer, than on any other branch of investigation pursued in the different centres of research supported by the Campaign.

It is of interest to see to what extent the subjects of study are representative of cancer research in other parts of the world by a comparison with the papers presented at the Fourth International Cancer Congress held at St. Louis last September. More than 75 per cent of the 260 odd papers given at the Congress were by scientific men from the United States, and it should be noted that their papers tended to be finished products, whereas the Campaign's report is rather more a statement of progress. Any such comparison is certainly liable to errors, for a number of reasons; nevertheless, the accompanying table will probably give an approximate idea of the relative precedence of the different lines of research with which the cancer problem is attacked.

	4th International Cancer Congress, 1947	B.E.C.C. Report, 1947
Radiation therapy and theory; use of radio-isotopes	35	18
Biochemistry of tumours and tumour bearers; nutrition; enzymes; nucleoproteins	33	12
Carcinogens, carcinogenesis	32	13
Chemotherapy	32	7
Pathology and diagnosis	25	5
Hormones in cancer	20	2
Advances, clinical and surgical	13	5
Organisation (research and clinical)	12	—
Cytology and cytochemistry	11	1
Genetics and mutation	9	2
Comparative oncology	9	—
Tissue culture	8	2
Experimental pathology	8	6
Milk factor	8	1
Virus tumours	5	6
Social, racial and industrial cancer	5	1

Only a few of the interesting investigations described in the Campaign's report can be referred to in this review and some important work will unfortunately receive no mention.

It need scarcely be stated that much essential clinical investigation has been carried out at all medical centres, and an elaborate report of the Clinical Cancer Research Committee analyses nine hundred cases of cancer of the colon from every etiological, pathological and clinical angle.

The increasing prominence of physics in cancer research is chiefly due to developments in the technique and theory of radiotherapy, in the use of radioactive isotopes, in the field of microscopy and in the application of physical chemistry to the study of carcinogens. The electronic characteristics and structural properties of carcinogens are now being used to explain why some compounds are carcinogenic and others not.

Haddow, at the Royal Cancer Hospital, recently arranged a meeting which Dr. Pullman from Paris was invited to address on a theory of electronic characteristics and carcinogenic activity of hydrocarbons. At this discussion, Dickens neatly hit the nail on the head by pointing out that the proof of any such theory would be its capacity to predict the structural requirements for a 'super-carcinogen'.

If the emphasis at the present time is favouring the physicist, the organic chemist has found at least one sphere for new synthetic work, that of chemotherapy, for another class of compounds has been introduced, the nitrogen mustards (for example, methyl-*bis*-(β-chloroethyl) amine). The large number of papers on chemotherapy presented at the International Congress shows how intense is the search for some drug which will selectively destroy cancer cells. The interest in chemotherapy would probably be greater than that suggested by the table if the hormone investigations directed to hormone therapy were included.

Unfortunately, the extreme caution with which therapists are compelled to state their results has a decidedly chilling effect on the reader: for example, they are apt to speak of "some degree of amelioration, although the response is usually transient", or "every case of Hodgkin's disease has shown a good although temporary response to the drug", or "it is doubtful whether any retarding influence has been present in our cases". Research, or rather experimentation, in this field is still highly empirical, dare one say, haphazard; this is inevitable, for we still have very little knowledge of the vulnerability of cancer tissue.

Passey and his collaborators in Leeds are working with the transmissible milk factor for mouse mammary carcinoma, and have elegantly demonstrated by the electron microscope the presence of macromolecular particles of definite size only in those tissues and secretions where the factor has been detected by the biological method. The further progress of these experiments will be awaited with much interest.

The mode of action of carcinogens is claiming more attention, to the satisfaction of those who see little purpose in the continued multiplication of new synthetic carcinogens. Selbie, at the Middlesex Hospital, and also the Edinburgh workers, have studied carcinogenesis by urethane on the lung of the mouse. They suggest that some tissue is stimulated to proliferation at a rate disturbing to tissue equilibrium, and that the urethane poisons a defence mechanism, allowing some other agent, perhaps a virus, to attack the cells and bring about malignancy. It may perhaps be objected that such an explanation scarcely does more than move the difficulties one step farther back.

Orr, at Leeds, comes to somewhat similar conclusions, namely, that the lung adenomata evoked by urethane supervene on an inflammatory process, and that mice, the lungs of which are particularly liable to pneumonic conditions when treated with urethane, are also more liable to lung tumours.

Dickens has succeeded in showing that saturated compounds can be dehydrogenated to the aromatic state by rabbit blood and by slices of muscle, kidney and spleen. The interest of this reaction lies in its bearing on a popular theory of cancer: that polycyclic saturated compounds in the body (cholesterol, sex hormones, bile acids) can by some error of metabolism be dehydrogenated to polycyclic aromatic carcinogens. Similar studies are being made by Shoppee at the Royal Cancer Hospital on the possibility of the conversion of 17 α-methyl-*D*-homoandrostane to carcinogenic methylchrysenes.

Berenblum has been working on the mechanism of the carcinogenic process with the aid of co-

carcinogens, and also on the nature of the cancer-producing factors in addition to benzpyrene which are present in tar. This work, and the experiments of Woodhouse at Birmingham on petroleum, might give valuable information if an attempt were made on the part of a government inspectorate to assess the risks of using certain petroleum products. However, any such tests and recommendations would have little effect so long as industrial substances which are carcinogenic are not handled entirely by mechanized processes.

Glücksmann, at Cambridge, has treated mouse tissue with X- and γ-rays in combination with co-carcinogens to see if the same synergistic effect can be observed as with chemical carcinogens. No such effect was detected, and histological examination showed profound differences between the papillomas induced by radiations and those induced by benzpyrene. Also at the Strangeways Laboratory, Lasnitzki has found that when an adenocarcinoma in mice is irradiated with X-rays, two-thirds of the injurious effect on the tumour is indirect and is brought about by changes in the still normal tissue surrounding the tumour. Thus the conclusions of Koller, arrived at by studies on irradiated tumours in human subjects, have been confirmed experimentally.

Peacock, at Glasgow, has investigated the co-carcinogenic action of croton oil added to overheated (365°) edible oil in feeding experiments on mice. He found that cancerous changes were brought about in the alimentary tract, although the proportion of positive results was much smaller than in experiments with carcinogenic hydrocarbons on skin or connective tissues. Similar tests on mice mutants produced by methylcholanthrene (Strong) which are particularly liable to gastric cancer might show facilitation of the effect of feeble carcinogens in the diet.

Pybus and Miller, at Newcastle, and also Carr, at Edinburgh, have been studying gene mutation produced by the administration of carcinogenic hydrocarbons to mice. The mutation theory has had an eventful career in cancer research. One of the first to propose that cancer cells are mutant forms of normal cells was Boveri, in 1912. X-rays and radium had long been known to be carcinogenic, when Muller in 1928 discovered that X-rays greatly increased the spontaneous mutation-rate in *Drosophila*. During the War, Auerbach *et al.* found mustard gas to be a potent mutagen; but unfortunately for the theory, Berenblum had shown that it prevents carcinogenesis by the hydrocarbons. Strong's discoveries have now been followed by a report from Demerec that benzpyrene and other carcinogenic compounds bring about mutations in *Drosophila*. He finds about 84 per cent correspondence between carcinogenic and mutagenic potentiality in a number of compounds given to the fruit fly in the form of a fine mist.

Sir Ernest Kennaway and Lady Kennaway are continuing their statistical work on the Registrar General's returns, and point out that in eighteen years the deaths from cancer of the lung in England and Wales have increased 16½ times in men (nearly 6,000 in 1945) and 8 times in women, although diagnosis must have been doubtful in some cases.

One of the most interesting conclusions in this investigation runs: "Cancer of the lung differs from that of the upper alimentary tract, larynx and skin in showing no inverse relation to ascent in the social scale (Stevenson, 1923). This suggests an airborne factor, as owing to the mixing action of the wind, there is less difference in the outdoor air breathed by different classes than in other social conditions such as food and cleanliness."

Hieger, in experiments on endogenic carcinogens, finds that these substances are concentrated in the cholesterol-rich fraction of tissues, not only from cancerous and non-cancerous human subjects, but also in commercial cholesterol obtained from cattle brain and spinal cord or from fish livers. Some recent results were described in this journal ("Carcinogenic Activity of Preparations Rich in Cholesterol", *Nature*, **160**, 270; 1947).

OBITUARIES

Dr. Bernard S. Dyer

THE death of Dr. Bernard Shirley Dyer on February 12, in his ninety-second year, marks the passing of one of the very few remaining pioneers of agricultural chemistry of the late nineties.

Born in London on February 25, 1856, the son of J. A. Dyer, a well-known London journalist, Bernard Dyer was educated at the City of London School. On leaving school at the age of seventeen he became a pupil assistant in the laboratory of Dr. Augustus Voelcker, consulting chemist to the Royal Agricultural Society, spending three years there and later taking the University of London degree of B.Sc. In 1877, at the early age of twenty-one, he established his laboratory at 17 Great Tower Street, London, where he remained until the laboratory was destroyed in the 'blitz' of May 1941. Here, while engaged in building up a practice in agricultural and food chemistry, he devoted much time in his earlier years to the publication of a series of agricultural articles in the scientific and lay Press, and also undertook a very considerable amount of lecturing throughout the country. About this period he was appointed consulting chemist to the Devon Agricultural Society, and later to the Essex and Leicestershire Societies.

There can be little doubt that Bernard Dyer's training with Voelcker had led to a specialization in agricultural chemistry which determined his future trend and the major interest in his life. Year after year, papers were published dealing with field investigation work, and, in particular, with the use and application of fertilizers and the necessity for far larger amounts than was then customary in Britain. Then came some years of work on the vexed question of soil analysis as a means of indicating the availability of the mineral constituents of the soil. The suggestion had already been made by Sachs that plants extracted their mineral food from the soil by the solvent action of the root sap exuded from their root hairs, and Tollens and Stutzer had suggested the use of a 1 per cent solution of citric acid for the assessment of the relative 'availability' of phosphatic fertilizers. Bernard Dyer attacked the problem from this new angle. He first determined in his laboratory the root acidity of about a hundred plants, and found the average figure to be the equivalent of 0·9 per cent citric acid—a figure substantially that suggested by Tollens and Stutzer. He then, in 1889, systematically analysed soil samples from twenty-two plots of Hoos Field, Rothamsted. The outcome of this work was the elaboration of the now well-known method of soil extraction using a 1 per cent citric acid solution. This was published in the *Journal of the Chemical Society* in 1894, and for this investigation the

University of London granted him the degree of D.Sc.

The next years were devoted to the larger task of examining the soils of the historic Broadbalk wheat field, including plots manured and unmanured for fifty years. The results of this work were recorded in 1901 in the *Philosophical Transactions of the Royal Society* in a paper entitled "A Chemical Study of the Phosphoric Acid and Potash Contents of the Wheat Soils of Broadbalk Field, Rothamsted". The paper was published shortly after the death of Sir John Lawes, to whom the inspiration of this particular investigation had been due. Shortly before this, in 1900, Dyer delivered the triennial course of Rothamsted American Lectures at Newhaven, U.S.A., afterwards published by the United States Department of Agriculture under the title of "Results of Investigations of the Rothamsted Soils". In 1893 he published a little book, "Fertilizers and Feeding Stuffs"; and in 1924 a book on "The Manuring of Market Garden Crops", this latter being a record of the results obtained from more than twenty years of field experimental work in Kent.

Turning to his other great activity, Bernard Dyer became an original member of the Society of Public Analysts in 1875, and to the affairs of this Society he gave much of his time, first as a member of council in 1880, and then as joint honorary secretary during 1883–96, when he was elected president in succession to Sir Thomas Stevenson. He contributed many papers to its journal, *The Analyst*, and, in collaboration with Dr. C. Ainsworth Mitchell, prepared its history, "Fifty Years of the Society of Public Analysts". He was elected an associate of the Institute of Chemistry during the year of its formation (1878) and became a fellow in 1880. He was an original member of the Society of Chemical Industry, and acted as chairman of its London Section during 1923–24. He held official appointments as agricultural analyst, as public analyst, and as official analyst to the London Corn Trade Association.

Dyer married twice, first Alice Collett, and secondly in 1890 Edith Steel, who survives with two of their three daughters.

Dr. Bernard Dyer will be remembered by all his friends for his great personal kindliness and charm. As a member of many societies, he was greatly esteemed by his colleagues and held in the greatest affection by his juniors, who remember his kindly help in their struggling years. As an analyst he was austere in the conception of his duty in seeking the truth.

G. TAYLOR

We regret to announce the following deaths:

Mr. Griffith Brewer, president during 1940–42 of the Royal Aeronautical Society, and a pioneer of aeronautics in Great Britain, on March 1, aged eighty.

Prof. R. T. Chamberlin, emeritus professor of geology in the University of Chicago, aged sixty-six.

Dr. A. L. Du Toit, F.R.S., lately consulting geologist to the De Beers Consolidated Mines, on February 25, aged sixty-nine.

Mr. G. S. W. Marlow, secretary of the Faraday Society, on March 5.

Sir Charles Grant Robertson, C.V.O., principal and vice-chancellor of the University of Birmingham, on February 28, aged seventy-eight.

NEWS and VIEWS

Radio Research in Great Britain: Dr. R. L. Smith-Rose

In 1920 the Department of Scientific and Industrial Research, guided by a newly formed Radio Research Board, started research in radio, which had grown in importance during the First World War. Most of the work was done at a field station at Slough under R. A. (now Sir Robert) Watson-Watt, and at the start attention was mainly devoted to investigations on atmospherics, direction-finding and the propagation of waves over the ground. When, in 1924, Appleton and Barnett demonstrated the reflexion of radio waves from the ionosphere, they asked the co-operation of Slough in fundamental experiments which laid the foundations of our present knowledge of the subject. Later, much of this experimental work was transferred to Slough, still under Appleton's guidance, while he continued his own work at Cambridge. In this way there grew up at Slough a team skilled in the use of pulses for the determination of distance by radio methods, which was able to turn its energies to the development of radar when the time came. In 1933 Slough and other radio research stations under the Department of Scientific and Industrial Research had been formed into a Radio Division of the National Physical Laboratory, with Watson-Watt as superintendent. In 1935 he took away a small team of experts to start a secret radar establishment, and Dr. R. L. Smith-Rose succeeded him. Just before, and during, the War, the ionospheric investigations at Slough developed so as to provide a world-wide organisation for the forecasting of propagational conditions on different wave-lengths, and there has, in addition, been considerable work on direction-finding, the propagation of ultra-short waves through the troposphere, the development of *radio sonde*, and the measurement of the electrical properties of soil and water at radio frequencies.

A new arrangement has recently been announced by which it is intended to combine the work at the National Physical Laboratory and Slough and to transfer it to a new establishment under Dr. Smith-Rose as director of radio research. The new establishment will, by this arrangement, have a director who has been personally active in several lines of research. In the early days at Slough he was engaged, with Barfield, in investigations of the propagation of waves over the surface of the earth and in problems of direction-finding. The study of propagation led him to work on the electrical properties of soil and water, and to investigate the forward tilt of waves travelling over the ground; the work on direction-finding led to a clear understanding of the part which the wave deviated by the ionosphere can play in producing errors in a loop direction-finder, and to an explanation of the errors produced by conducting bodies near the loop, the so-called site-errors. He has published papers on the propagation of waves through the troposphere and on improved methods of direction-finding, particularly on very high frequencies. He has been chairman of the Radio Section of the Institution of Electrical Engineers, and was decorated with the United States Medal of Freedom with Silver Palm for his work in radio during the

War. Under Sir Edward Appleton's able guidance, Britain has established a lead in the scientific applications of radio, which the country will look to the new Radio Research Establishment to improve. With the present team under Dr. Smith-Rose, and with Sir Edward at the head of the Department, they are not likely to be disappointed.

Deputy Scientific Adviser to Army Council: Prof. F. J. M. Stratton, O.B.E., F.R.S.

THE appointment of Prof. F. J. M. Stratton to the post of deputy scientific adviser to the Army Council has been announced. Prof. Stratton's retirement from the chair of astrophysics at Cambridge last October was announced in *Nature* (**159**, 463; 1947), and the record of his scientific work was noted. His was a retirement dictated by the rules of superannuation, and not by any loss of activity; so that his choice for and acceptance of this further post will be no more a surprise to his friends than his own preference for further service to merited retirement. The War Office is fortunate in securing the services of so able a man of science, particularly one who has given proof, through ten years service in the Army in two wars and a long association with the Cambridge O.T.C. and the Territorial Army, of his aptitude and interest in military affairs. While his appointment will be a temporary one for a limited period, the acquisition to the Scientific Civil Service, even for a short time, of such men as Prof. Stratton will be a source of strength to the Service, and the experience and leadership he can give to some of the younger men of science employed by the Army, in operational research and other tasks, will obviously be of the greatest value to them.

Willard Gibbs Medal: Prof. Carl F. Cori

PROF. CARL F. CORI, professor of biochemistry in the Washington University School of Medicine, has been awarded the 1948 Willard Gibbs Medal of the Chicago Section of the American Chemical Society. This medal, one of America's highest scientific honours, goes to Dr. Cori for his achievements in research on the processes by which the body converts sugar into energy. He has been a leading worker in the difficult field of biological carbohydrate transformations for many years. His contributions have been of widespread importance involving adrenal, cortical, pituitary, and pancreatic roles in carbohydrate utilization as well as carbohydrate metabolism in tumours. A recent outstanding contribution is at least a partial solution of the problem of how insulin functions. He and his wife, Dr. Gerty T. Cori, who is also a professor of biochemistry in Washington University, received the Nobel Prize for Medicine for 1947 (see *Nature*, **160**, 599; 1947) for determining the process by which the body stores sugar in the liver as glycogen, or animal starch, and then reconverts the glycogen to sugar as it is needed.

Library of the Royal Society: Mr. H. W. Robinson

ON March 31 Mr. H. W. Robinson retires from the office of librarian of the Royal Society. He joined the staff of the Society in 1902, when as a boy of fourteen he assisted both the chief clerk and the librarian. His work soon became exclusively associated with the Society's Library; in 1930 he was raised from assistant to the post of assistant librarian and five years later to the position which he now holds. This forty-six years service to the Society has been twice broken by war. In the First World War Mr. Robinson served in the army with distinction; in the Second World War there was a period of service on the Central Register, which came between the strenuous work which he performed in seeing the Society's manuscripts and early printed books safely to Wales and his recall to the Society's service in 1943. Since then he has had the exacting but pleasant task of seeing the Library's books brought back from Oxford, where they had been stored by the Bodleian Library, and arranged in their places with a minimum of inconvenience and disturbance.

Mr. Robinson has a unique knowledge of the Society's Library and in particular of its extensive and priceless archives, a knowledge which he has always been delighted to put at the disposal of the scholars, from many countries, to whom his learning is well known. His intimate acquaintance with the Society's traditions and records has found expression in his services to the history of science. He is, for example, an authority on Robert Hooke, having edited, in conjunction with Mr. Walter Adams, the Diary in the possession of the Guildhall Library and having identified as another Diary of Robert Hooke the manuscript in the British Museum previously attributed to James Petiver. With Prof. Harcourt Brown and Dr. D. McKie he founded the *Annals of Science*, and he was actively associated with the foundation of the British Society for the History of Science, of which he is honorary treasurer. He has an intimate knowledge of many aspects of the bibliography of Isaac Newton, in particular of his manuscripts, and it has been arranged that after his retirement his services shall still be available to the Society, to assist Prof. H. W. Turnbull in editing the Newton letters. It is to be hoped that for many years to come Mr. Robinson's familiar figure will be seen about the Royal Society Library, working among the manuscripts that he loves so well.

Reports on German War-time Industry and Science

REPORTS of war-time scientific and industrial activities in Germany have been available to interested parties for some time. These reports were prepared by B.I.O.S. (British Intelligence Objectives Sub-Committee), its American counterpart, F.I.A.T. (Field Information Agency, Technical), and the combined Anglo-American Agency, C.I.O.S. (Combined Intelligence Objectives Sub-Committee) which preceded them. Actual investigations in Germany ceased at the end of June 1947. To date, 2,720 reports have been issued. It is stated that more than one million copies have been sold or distributed to the universities, learned societies, trade and research associations and principal public libraries of Britain. The Board of Trade has now arranged for experts in each of the major fields to prepare critical summaries suitable for publication. These reports will be known as "B.I.O.S. Overall Reports" and there will be fifty of them, all of which are expected to be printed by the end of June. The first, on the petroleum and synthetic oil industry of Germany, has been published; the next six reports will be on shipbuilding and marine engineering, the German timber industry, the glass industry, the German road system, agriculture, and the rubber industry. All inquiries about these reports should be addressed directly to the Board of Trade, T.I.D.U., Research Section, 40 Cadogan Square, London, S.W.1.

The Foreign Office announces the publication and distribution of the first volumes of the "FIAT Review of German Science", compiled by German experts under the direction of the British, American and French Field Intelligence Agencies (Technical). The Review is written in German and covers fundamental research in pure science during the years 1939–46. By agreement between the British, American and French agencies, the first printing is a restricted edition for official distribution between the three Allies and U.N.E.S.C.O. The British share of about 250 sets will be issued to Government and other bodies within the Commonwealth, to universities and medical schools and to the libraries of certain learned and professional societies. It is hoped that the edition will be completed within the next six months. The Allied edition of the FIAT Review will be followed by a German edition. The latter, also printed in German, will be published by Dieterich'sche Verlagsbuchhandlung, Wiesbaden, Germany, and will be obtainable through normal trade channels. It is understood that volumes will not be sold separately but only in sets comprising the titles under the headings physics, chemistry, mathematics, medicine, biology and sciences of the earth.

Eclipse Observations for Geodesy

It is now possible to amplify the brief reference in *Nature* of February 7 (p. 196) to the application to geodesy of the times of contact to be observed at different stations on the track of the annular eclipse of May 8–9, 1948. The first suggestion that such observations might provide information as to the earth's shape over areas where geodetic triangulation is impracticable was made by Mr. G. E. Barton (*Mon. Not. Roy. Ast. Soc.*, **64**, 105; 1926). His observations at Benkoelen at the eclipse of January 14, 1926, were spoilt by an unfortunate accident, but the idea was afterwards adopted, and expeditions from a number of countries used improved methods of time determination of such observations at the total eclipses of 1945 and 1947 by parties well separated in longitude. For the annular eclipse of next May, the National Geographic Society of the United States has prepared an elaborate scheme of observations at seven ground stations from Mergui in southern Burma to Kiska in the Aleutians. These will be supplemented by observations from aeroplanes of the U.S. Air Force; photographs of the eclipse will be taken from above the clouds from positions determined by short-range radar navigational methods.

The U.S. Army's Map Service, Engineer and Signal Corps, the U.S. Navy, Air Force, Bureau of Standards, Coast and Geodetic Survey and State Department will co-operate with the National Geographic Society in the scheme. The leaders of the different parties are to be as follows: at Mergin, Mr. E. A. Halbach; at Bangkok, Prof. Charles H. Smiley with Prof. C. W. Miller; at Wu-K'ang, China, Father Francis J. Heyden with Dr. V. C. Chang; at Cho-nan, Korea, Dr. George van Biesbroeck; at Kiska and Adak, Lieut.-Cmdr. Clarence R. Reed and Mr. Clarence A. Shelton; while at the Japanese island of Rebun Jima there will be a Japanese astronomer selected by Prof. Hagihara, of the Tokyo Observatory. This marks a welcome move towards international co-operation in science between Japan and the United States. Measurements of the times of contact will be made by photographing the eclipse on 35-mm. sound motion pictures which will record the ticks of a chronometer on the sound track. The chronometers will be checked and rated from radio time-signals. The techniques which make these observations practicable have been developed to a high degree of efficiency in the last twelve years.

Journal of the Institute of Navigation

The recently founded Institute of Navigation, the headquarters of which for the present are at the Royal Geographical Society, Kensington Gore, London, S.W.7, has issued the first number of its quarterly *Journal* (London: J. Murray. 25*s*. per annum). The object of the Institute is to unite those interested in the science and art of navigation, both by sea and in the air. Fellows are those who are either professional navigators or who have made outstanding contributions to the science of navigation; members are those who are generally interested. The Astronomer Royal is president of the Institute, and he has contributed to the new *Journal* an introductory address on the development of navigation. Other articles are on radio aids to navigation, consol, pressure pattern flying and many other topics. The new ocean weather service also finds a place: its ships, equipment and tasks are explained. The *Journal* promises to be a useful addition to the list of scientific periodicals.

Plant Disease Charts

Plant Protection, Ltd., has recently issued two useful wall charts illustrating common and important crop diseases and pests. Both charts are beautifully produced in colour, depicting parts of the plants diseased and the insects where such are concerned. One is entitled "Some Crop Pests and Diseases" and illustrates and describes the following: tomato blight, celery leaf-spot, celery leaf miner, cabbage white caterpillar, black aphis, potato blight, carrot fly, turnip flea beetle, onion mildew, chocolate spot of broad bean, mole cricket, locust, pea and bean weevil, leatherjacket, wireworm, cutworm. The other, "Pests and Diseases of Apples", deals with brown rot, woolly aphis, sucker, apple and pear scab, winter and March moths, sawfly, capsid bug, codling moth, apple blossom weevil and apple mildew. Methods of prevention or protection are shortly described in each case. These wall charts will be a valuable visual aid for schools and agricultural colleges and institutes, which can obtain copies free of charge from Plant Protection, Ltd., Yalding, Kent.

Biology of Lice

A second edition of the booklet entitled "Lice" by Dr. John Smart, published as Economic Series No. 2A by the British Museum (Natural History) has recently appeared (British Museum (Natural History), London, S.W.7, 1948. 9*d*.). It deals with the incidence, development and habits of lice affecting man and the best methods for controlling these pests. During the six years interval that has elapsed since the appearance of the first edition of this booklet, much new knowledge concerning lice has come to hand, especially relative to control measures acquired during the War. Information on these and other features are incorporated in the new edition.

International Conference on the Physics of Metals

The Netherlands Physical Society is organising an international conference on the physics of metals, to be held at Amsterdam during July 12–18, after the Assembly of the International Union of Pure and Applied Physics. The provisional programme

includes general lectures by Dr. R. Kronig (Delft) on the electronic structure of metals; Prof. L. Pauling (Pasadena) on valency in metals; Dr. H. B. G. Casimir (Eindhoven) or Prof. C. J. Gorter (Leyden) on superconductivity; Sir Lawrence Bragg (Cambridge) on slip in metals; Prof. N. F. Mott (Bristol) on work hardening and creep in metals; H. Borelius (Stockholm) on transitions in super-cooled metallic solutions; A. Guinier (Paris) on precipitations in metals; Prof. W. G. Burgers (Delft) on crystal growth; Prof. J. H. van Vleck (Harvard) on fundamentals of ferromagnetism. The reception committee in Amsterdam is prepared to give advice and to make hotel reservations. Particulars of the conference can be obtained from Prof. C. J. Gorter, Kamerlingh Onnes Lab., Nieuwsteeg 18, Leyden.

Summer School in Chemistry at Dublin

A SUMMER SCHOOL IN CHEMISTRY is being arranged by the Irish Chemical Association and will be held in the Department of Chemistry, University College, Dublin, during July 5–9. Four courses of lectures will be given: "Some Recent Advances in Chemotherapy", by Dr. V. C. Barry, of the Medical Research Council of Ireland; "Recent Advances in the Determination of the Structure of Organic Compounds", by Prof. W. Cocker, professor of chemistry, Trinity College, Dublin; "Recent Advances in Biochemistry", by Prof. E. J. Conway, professor of biochemistry and pharmacology, University College, Dublin; "The Electronic Theory in Chemistry", by Prof. T. S. Wheeler, professor of chemistry, University College, Dublin. Particulars of the School can be obtained from the honorary secretary, Irish Chemical Association, The Laboratory, 12 Dawson Street, Dublin, to whom applications to attend must be sent not later than June 26.

British National Committee for Crystallography

THE Royal Society, as the national body adhering to the newly formed International Union of Crystallography, has recently set up a British National Committee for Crystallography under the chairmanship of Sir Lawrence Bragg. The members of the Committee are: Prof. W. T. Astbury, Prof. J. D. Bernal, Mrs. D. C. Hodgkin, Mrs. K. Lonsdale, Sir George Thomson, Prof. C. E. Tilley (all representing the Royal Society), Dr. G. M. Bennett (Chemical Society), Mr. D. A. Oliver (Institute of Metals), Prof. E. G. Cox (Institute of Physics), Dr. C. Sykes (Iron and Steel Institute), Dr. F. A. Bannister (Mineralogical Society), and Dr. H. Wilman (Physical Society). In addition to the above, Prof. P. P. Ewald, Dr. R. C. Evans and Dr. W. H. Taylor as members of the provisional executive committee of the International Union are *ex officio* members of the National Committee. The first General Assembly of the International Union of Crystallography is being held at Harvard University during July 28–August 3.

Royal Society of Edinburgh: New Fellows

THE following have been elected fellows of the Royal Society of Edinburgh: Sir Robert Allan, 41 N. Castle Street, Edinburgh 2; Prof. J. F. Allen, Department of Natural Philosophy, University of St. Andrews; Mr. Alexander Cullen, architect and town planning consultant; Dr. F. J. Elliott, head of the Department of Physiology, Royal (Dick) Veterinary College, Edinburgh; Dr. M. A. Ellison, principal scientific officer, Royal Observatory, Edinburgh; Major M. D. W. Elphinstone, Threeways, Highfield Road, Chislehurst, Kent; Prof. T. H. Fraser, Department of Economics, Fouad I University, Cairo; Sir John Fryer, secretary of the Agricultural Research Council; Prof. T. N. George, Department of Geology, University of Glasgow; Dr. John Morrison Hay, deputy director and head of Engineering Division, Scottish Seaweed Research Association; Dr. J. F. Heggie, senior pathologist, North Middlesex County Hospital; Dr. G. O. T. D. Henderson, officer-in-charge, Oceanographic Laboratory, Leith; Dr. L. G. W. Hill, lecturer in pharmacology, University of Edinburgh; Dr. W. C. O. Hill, lecturer in physical anthropology, University of Edinburgh; Prof. E. L. Hirst, Department of Organic Chemistry, University of Edinburgh; Mr. E. P. Hudson, director, Scottish Agricultural Industries, Ltd., Leith; Prof. W. Q. Kennedy, Department of Geology, University of Leeds; Mr. J. Gibson Kerr, 51 Castle Street, Edinburgh 2; Dr. D. N. Lawley, lecturer in statistics, University of Edinburgh; Dr. T. N. MacGregor, lecturer in gynæcological endocrinology, University of Edinburgh; Dr. A. P. Orr, deputy director (senior principal scientific officer), Millport Laboratory, Scottish Marine Biological Association; Dr. R. Passmore, lecturer in clinical and industrial physiology, Department of Public Health and Social Medicine, University of Edinburgh; Dr. T. R. Tannahill, lecturer in astronomy, University of Glasgow; Dr. S. I. Tomkeieff, lecturer in geology, King's College (University of Durham), Newcastle-upon-Tyne; Prof. C. H. Waddington, Department of Animal Genetics, University of Edinburgh, director of the Genetics Laboratory of the Animal Breeding and Genetics Research Organisation of the Agricultural Research Council.

Announcements

THE James Tait Black Memorial Prize of the University of Edinburgh for 1947, awarded for a biography or work of that character, has been awarded to Dr. C. E. Raven, regius professor of divinity in the University of Cambridge, and master of Christ's College, for his book "English Naturalists from Neckham to Ray" (see this issue of *Nature*, p. 373).

DR. J. E. KEYSTON, formerly assistant director of scientific research, Admiralty, has been awarded the United States Medal of Freedom with Bronze Palm for promoting interchange of scientific and engineering information and collaborating with American research groups during the Second World War. The investiture took place in Salisbury, Southern Rhodesia. Dr. Keyston has recently been appointed research secretary of the Central African Council (see *Nature*, February 14, p. 230).

THE Committee of Privy Council for Medical Research has appointed Prof. H. P. Himsworth, professor of medicine in the University of London, to be a member of the Medical Research Council.

THE Council of the Royal Statistical Society offers the Frances Wood Memorial Prize, value £30, for competition in 1948. The Prize is offered for the best investigation, on statistical lines, of any problem bearing directly or indirectly upon the economic or social conditions of the people. Essays (which must be either printed or typed, and accompanied by copies of all statistical tabulations and diagrams) must be sent to the honorary secretaries of the Royal Statistical Society, 4 Portugal Street, W.C.2, not later than December 31, 1948.

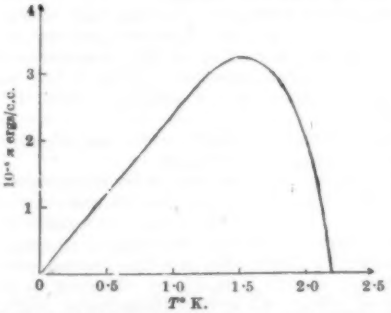
LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications

Liquid Helium II

THE classical theory of liquids[1,2,3], of which a general explanation was given by Prof. Max Born and me in a previous article[4], and the quantization of the theory[5,6] which followed, led to a conception of the nature of viscosity and thermal conduction in liquids which we hoped would contribute towards the understanding not only of normal liquids, but also of 'quantum liquids', of which helium II and the electrons in superconducting metals are known examples.

The detailed application of these results to helium II has now been completed, and it has been found possible, without further assumption, to explain all the well-known properties of this liquid. The essential feature of a quantum liquid, as we observed previously[6], is the distinction between the intensive properties defined thermodynamically and from the point of view of kinetic theory. Of special importance is the distinction between the 'thermodynamic' pressure p, defined in terms of the work done pdV during the displacement of a surface in the liquid, and the 'kinetic' pressure p_1, the gradient of which determines the mean motion of the molecules. It can be shown that the difference π between these two quantities first becomes numerically significant just below the λ-point; it is represented as a function of temperature in the accompanying figure.



π AS A FUNCTION OF TEMPERATURE AT THE SATURATION VAPOUR PRESSURE

The equation of motion of the quantum liquid is

$$\rho \frac{du}{dt} + \frac{\partial p}{\partial x} = -\frac{\partial \pi}{\partial x}, \qquad (1)$$

where ρ is the density and u the macroscopic velocity. It follows rigorously that a reformulation of the first law of thermodynamics is required below the λ-point, of such a kind that it reduces to the usual law

$$dQ = dU + pdV \qquad (2)$$

for the ideal quasi-static process, but has quite a different form

$$dQ = d(U - \pi V) + p_1 dV \qquad (3)$$

for steady motion, such as is observed in the transfer effect (studied in detail by Daunt and Mendelssohn[7]), and yet another form

$$dQ = d(U + \pi V_0 - \pi V) + p_1 dV \qquad (4)$$

for wave motion, V_0 being the rest volume of the liquid. The anomalous specific heat and density of helium II is thus explained by the presence of thermal waves. Similar waves have been observed in ordinary liquids[8], but are strongly damped and have only a small group velocity.

A thermal wave transfers heat energy and the liquid bulk in opposite directions in a ratio depending only on the temperature. Kapitza's experiments[9] on the thermomechanical effect in a narrow slit have a quantitative explanation not, as Landau[10] suggests, in the motion of a superfluid at absolute zero, but in the almost isothermal passage of a thermal wave through the slit. Peshkov's observations[11] of temperature waves in helium II also have a quantitative explanation in terms of the thermal waves.

Earlier theories due to F. London[12,13] and Tisza[14,15] suggest that superfluidity is connected with the condensation which occurs in a Bose gas not far from the λ-point. A serious objection to these theories is the occurrence of entirely analogous phenomena in superconductors, where the electrons obey Fermi statistics. The quantum theory of liquids is, however, equally applicable to superconductivity, and an interesting feature of the theory outlined here is that it can explain also phenomena in superconductors: one requires only to replace the mechanical pressure by the electromagnetic stress tensor and to represent the almost stationary metallic ions by a conservative field of force.

H. S. GREEN

Department of Mathematical Physics,
University, Edinburgh.
Dec. 24.

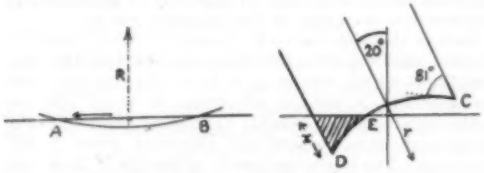
[1] Born, M., and Green, H. S., *Proc. Roy. Soc.*, A, **188**, 10 (1946).
[2] Green, H. S., *Proc. Roy. Soc.*, A, **189**, 103 (1947).
[3] Born, M., and Green, H. S., *Proc. Roy. Soc.*, A, **190**, 455 (1947).
[4] Born, M., and Green, H. S., *Nature*, **159**, 251 (1947).
[5] Born, M., and Green, H. S., *Proc. Roy. Soc.*, A, **191**, 168 (1947).
[6] Born, M., and Green, H. S., *Nature*, **159**, 738 (1947).
[7] Daunt, J. G., and Mendelssohn, K., *Proc. Roy. Soc.*, A, **170**, 423 (1939).
[8] Lucas, R., *J. de Phys.*, (7), **9**, 410 (1937).
[9] Kapitza, P. L., *J. Phys. U.S.S.R.*, **5**, 59 (1941).
[10] Landau, L., *J. Phys. U.S.S.R.*, **5**, 71 (1941).
[11] Peshkov, V., *J. Phys. U.S.S.R.*, **10**, 389 (1946).
[12] London, F., *Phys. Rev.*, **54**, 947 (1938).
[13] London, F., *J. Phys. Chem.*, **43**, 49 (1939).
[14] Tisza, L., *C.R. Acad. Sci., Paris*, **207**, 1035, 1186 (1938).
[15] Tisza, L., *J. de Phys.*, (8), **1**, 165, 350.

Theory of Skating

IT is perhaps less common than it was to find the phenomenon of regelation put forward as a complete explanation of skating. Very probably anyone with a scientific education will suspect that plastic flow in the solid ice plays an important part, and the following observations will, if they are accepted, serve to strengthen that opinion.

It is clear at once that regelation as ordinarily understood in this case must require a rapid flow of heat through the skate blade from back to front, and yet the temperature gradient must be an infinitesimal one. Obviously the effect of friction must also be included, and since the publication of Bowden and Hughes' paper[1] in 1939 it has become possible to calculate what this may be. What no one seems to know with any accuracy is the depth of penetration of the skate blade and the amount of ice actually displaced. This is not easy to determine experimentally, and for present purposes the results have been

calculated from simple observations using a skate ground to accurately known dimensions. Skates are usually ground to a form decided more or less empirically, the radius of curvature of the blade not being constant along the length. It is therefore important to record that a skate of uniform vertical radius (R) 72 in. and transverse radius (r) 0·5 in. performs admirably and possesses, indeed, some superiority over the ordinary run[1]. The blade has a thickness of 5/32 in. and the angle between the side of the skate and the bottom edge is accordingly 81°. In the calculations, this skate is considered at an angle of 20° to the vertical and is supposed to carry a load of 10 stones weight.



The depth of penetration of the blade is clearly a question which depends on the pressures concerned: the skate will sink in until the area in contact is such that the pressure is insufficient for further sinking. Curiously enough, this matter turns out to be less uncertain than might be expected. Double lines such as would be (and are) formed when the edge C comes in contact with the ice are always avoided in competitions, and the fact that they can be avoided at angles of about 20° (got from photographs) shows that the penetration must have an upper limit which with this particular skate is about 1/32 in. From this it follows that 0·0018 c. in. (or 0·03 gm.) of ice are displaced per length AB: the chord AB being in this case 4·38 in. The heat required to melt this ice is then 2·4 cal.

Friction can account for very little of this. From the equation

$$Q = \frac{Mg\mu_k}{J} L,$$

where M is load and L is AB, we find (using Bowden and Hughes' value for μ_k for *brass* on ice) only 0·363 cal. per length AB (AB = 4·38 in.). The ice melted would therefore be only 0·0045 gm.—about one eighth of the amount estimated to be displaced.

To estimate the regelation effect without reference to the difficulty about heat flow, we may find how deep the skate would sink under the stated load if there is a temperature gradient in the ice of the sort existing in rinks. 10° C. per in. is here quite a common gradient; out of doors the conditions are, of course, very variable; but a surface temperature of 0° C. seems to be the best for skating, and at low temperatures when there is a hard frost skating is more difficult.

The freezing-point lowering being given by

$$t = 0{\cdot}0072\,P,$$

where P is the pressure in atmospheres, it remains to find the area in contact with the ice at a penetration of 1/32 in. The arc DE having a value of 0·0744 in. when x = 0·0313 in., the area is approximately given by 2·2 (0·0313 + 0·0744), which comes to 0·233 sq. in. From this the freezing point comes out at about − 0·3° C.—or a depth of 0·03 in. below the surface, which is of the correct order.

Nevertheless, this static picture will not do. At 10 m.p.h., heat would have to flow from B to A at some 100 cal. per sec.: an impossible rate having regard to the conductivity of steel, the cross-section area and the temperature difference of only a fraction of a degree centigrade. It looks very much more likely that the skate makes its track in the ice through plastic deformation of the solid rather than that melting plays any great part. The pressures applied to the ice by a moving skate must be of the order of some thousand pounds per square inch, and under such a stress the ice would give way. It is of interest, however, in regard to the question of friction, to note that Bowden and Hughes state that the lowest coefficients of kinetic friction were obtained when a water film of the order of 7×10^{-3} cm. thickness is present. The water formed by friction in the present case would allow of a layer of some 5×10^{-3} cm. thickness, and this might be sufficient for lubrication.

A. E. Bell

Science School,
Clifton College,
Bristol.

[1] *Proc. Roy. Soc.*, A, **172**, 280 (1939).
[2] Private communication from J. E. Sears, T. P. C. Low and C. S. d'E. Stock.

Chromatic Aberration of Electrostatic Lenses

The focal length of a three-aperture electrostatic lens follows from the general paraxial ray equation:

$$4\Phi r'' + 2\Phi' r' + \Phi'' r = 0,$$

where Φ is the potential along the axis (r = 0), and Φ_0 is the acceleration voltage.

When the potentials of cathode and intermediate electrode are equal, the chromatic aberration due to $\Delta\Phi_0/\Phi_0$ is zero according to this equation (although Φ_0 must be kept constant within 1 per cent to reduce the influence of external fields of transformers, etc.).

This is not so, however, when the relativity correction is taken into account.

The focal length is influenced by applying an extra constant voltage e between cathode and intermediate electrode. Chromatic aberration is caused by this extra voltage. It has proved possible to compensate the relativity aberration by this second chromatic aberration due to $\Delta\Phi_0/\Phi_0$ by choosing a suitable value of e/Φ_0. So every acceleration voltage determines its specific value of e/Φ_0.

When cathode and intermediate electrode potential of a certain weak electrostatic lens are equal (e = 0), the aberration due to relativity correction at 100 kV. is

$$\frac{\Delta A}{A} = -\,0{\cdot}14\,\frac{\Delta\Phi_0}{\Phi_0}, \qquad (1)$$

$1/A$ being the focal length.

Using a specific value of e/Φ_0 to eliminate this aberration, the constancy of e is determined by the chromatic aberration due to $\Delta e/e$.

$$\frac{\Delta A}{A} = -\,0{\cdot}16\,\frac{\Delta e}{e}. \qquad (2)$$

The advantage over the e = 0 type lenses follows from equations 1 and 2.

As the intermediate electrode is taking no current, stabilization of e causes no difficulties. The difficulty in stabilizing Φ_0 is that emission current is being

taken. The advantage over magnetic lenses is clear, chromatic aberration of this type being

$$\frac{\Delta A}{A} = C.\frac{\Delta \Phi_0}{\Phi_0},$$

where C is about 0·8.

W. A. Le Rütte
Institute for Electron Microscopy,
Delft. Nov. 17.

Absorption Band Spectrum of S_2 in the Schumann Region

While the main band-systems of the molecules O_2, S_2, Se_2 and Te_2 of the sixth periodic group have been the subject of numerous publications, there is little known about the systems of these molecules lying in the far ultra-violet. In all cases such systems have been found in absorption, but they have been analysed only partially for their complex structure. The absorption bands of Te_2 and Se_2 between 2500 and 1950 A. and 1950 and 1750 A. respectively have been photographed by Choong Shin-Piaw[1]. His analysis is incomplete and violates the empirical rule of Mecke–Birge. Choong Shin-Piaw believed all the molecules Te_2, Se_2 and S_2 to show the same peculiarity, and referred to the results published by Wieland, Wehrli and Miescher[2] on S_2. Yet these authors emphasized the provisional character of their interpretation.

We have therefore reinvestigated the S_2-bands between 1600 and 1900 A. by means of a 1-metre vacuum grating spectrograph (dispersion 8 A. per mm.). The continuum was furnished by a Lyman explosive discharge through a quartz capillary. Within the accuracy of measurement, which for most of the sharp bands is better than $\pm$ 1 cm.$^{-1}$, all the recorded bands can be arranged in two systems which we will call C and D.

The bands of system C are degraded towards shorter wave-lengths and appear to have several heads up to six, the intensity of which depends strongly from the vibrational quantum number v'. By arranging the strongest head of each band in a scheme, one gets for the wave-numbers of the heads the expression :

$$\nu = 55598{\cdot}2 + 830{\cdot}2\,(v' + \tfrac{1}{2}) - 3{\cdot}75\,(v' + \tfrac{1}{2})^2 - 725{\cdot}1\,(v'' + \tfrac{1}{2}) + 2{\cdot}85\,(v'' + \tfrac{1}{2})^2.$$

The system thus consists chiefly of the two vibrational progressions $v' = 0$ and $v'' = 0$. The vibrational constants of the lower level are in good agreement with the data of the ground-state of S_2 given by Olsson[3] ($\omega_e'' = 725{\cdot}8$, $\omega_e''x_e'' = 2{\cdot}85$). The high intensity of the bands points to a transition between states of like multiplicity. The ground-state being $^3\Sigma_g^-$, the upper state might then be of the $^3\Sigma_u^-$ or $^3\Pi_u$ type. Considering the number of heads and the multiplet separation, which is larger than in the ground-state, $^3\Pi_u$ is perhaps more probable.

System D, situated at shorter wave-lengths, is about of equal intensity, but its aspect is more complex. There are apparently three groups of bands (a, b, c in the accompanying reproduction) which are observed several times. Each group is formed by three strong heads. The groups being arranged in a scheme, the vibrational constants turn out to be nearly the same for all the heads. From the strongest heads on the more refrangible side of each group, the following constants are derived :

Group a		Group b		Group c	
ν_0	= 58515·1	ν_0	= 58707·2	ν_0	= 58976·8
ω_e'	= 794·2	ω_e'	= 793·8	ω_e'	= 793·7
$\omega_e'x_e'$	= 4·00	$\omega_e'x_e'$	= 4·00	$\omega_e'x_e'$	= 4·00
ω_e''	= 724·4	ω_e''	= 724·6	ω_e''	= 725·1
$\omega_e''x_e''$	= 2·85	$\omega_e''x_e''$	= 2·85	$\omega_e''x_e''$	= 2·85

Here again the lower level is identical with the ground-state of S_2. As an arrangement of the groups or systems in series of electronic states does not seem possible, no traces of higher series members being recorded, the three groups must be regarded as belonging to one and the same system showing atom-like separations. This analysis of system D departs from the one given earlier. The bands being shaded towards the violet, the vibrational frequency of the lower level is expected to be smaller than that of the upper one. This is actually the case.

The details of this investigation and a fuller discussion of the results will be given in a later paper to appear in the *Helv. Phys. Acta*.

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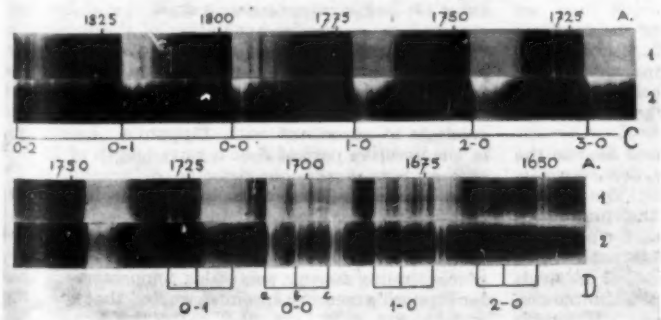

Absorption bands of overheated sulphur vapour between 1650 and 1850 A.
1. Saturation pressure = 0·5 mm. (t_s = 165° C.), temp. of oven = 630° C.
2. " " = 10 mm. (t_s = 245° C.), " " " = 630° C.

Energy of the Ground-State of Helium-like Atoms

The purpose of the present note is to suggest that the discrepancy between the measurements of helium-like spectra made by F. Tyrén and by H. Flemberg[1], on one hand, and the theoretical calculations made by E. Hylleraas (non-relativistic) and by me[2] (relativistic corrections) on the other hand, may possibly be due to the same reason which causes the discrepancy between theory (Dirac's fine-structure formula) and experiment (Lamb and Retherford[3]) in the hydrogenium spectrum.

The possibility of removing this latter discrepancy by taking into account the interaction of the electron with the radiation field has been the subject of discussions at a conference on Shelter Island

this year[4], and has inspired calculations by Weisskopf[5] and by Bethe[4].

According to Bethe's calculations, the shift of an ns level should become $W' \sim kZ^4/n^3$ cm.$^{-1}$, where the factor k is about 0·26 for $Z = 1$ and $n = 2$ and does not change very rapidly with Z and n. This agrees well with the observed level-shift.

This result can be applied to the ionization energy of helium-like atoms if as a first rough approximation the interaction between the two electrons is neglected. In the accompanying table I have calculated the ratio W'/Z^4, where W' is the difference between the calculated and the experimental ionization energy.

Z	W'	W'/Z^4
2	+ 14	0·88
3	+ 13	0·16
4	+ 84	0·33
5	+ 195	0·31
6	+ 311	0·24
7	+ 537	0·22
8	+ 1080	0·26
9	+ 1844	0·28
12	+ 4861	0·23
13	+ 4966	0·18

The value 0·88 obtained for $Z = 2$ is, of course, very uncertain, since the theoretical value lies within the experimental limits of error.

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Theory of the Anomalous Skin Effect in Metals

Pippard[1] has recently made an experimental and theoretical study of the skin effect in metals at high frequencies, in which he showed that the usual theory of the effect is no longer valid at low temperatures owing to the breakdown of Ohm's law when the free path of the conduction electrons becomes comparable with the penetration depth of the electric field. With the aim of putting Pippard's provisional theory of the anomalous effects on a more rigorous basis, we have reformulated his equations using the methods of the modern electron theory of metals, and we have succeeded in obtaining explicit solutions which make it possible to give a quantitative account of the phenomena to be expected over the whole frequency- and temperature-range.

We consider a semi-infinite metal and assume the electrons to be quasi-free, the energy being proportional to the square of the wave-vector. The relation between the current density and the (unknown) electric field at any point in the metal, for arbitrary values of the frequency ω and the free path l, can then be obtained by the usual statistical methods of the theory of metals based on the Boltzmann equation[2]. On combining this relation with Maxwell's equations, we obtain the following integro-differential equation for the electric field $f(x)$:

$$f''(x) = i\alpha \left\{ p \int_{-\infty}^{\infty} k(x-y)\, f(y)dy + (1-p) \int_{0}^{\infty} k(x-y)\, f(y)dy \right\}, \qquad (1)$$

where

$$k(u) = \int_1^\infty \left(\frac{1}{s} - \frac{1}{s^3} \right) \exp\{ -s(1 + i\omega\tau)|u| \}ds,$$

x is the distance into the metal measured in units of l, $\alpha = 3l^2/2\delta^2$ (δ being the classical skin-depth), τ is the time of relaxation of the electrons, and it has been assumed that a fraction p of the electrons is scattered specularly at the surface of the metal while the rest are scattered diffusely. Also, $f(x)$ is to be an even function of x. The basic equation of Pippard's treatment (*loc. cit.*, equation (7)) may be written in a form which differs only in minor detail from equation (1).

Equation (1) has been solved for the two limiting cases $p = 1$ and $p = 0$ by means of the theory of Fourier integrals[3]. The electric field is, in general, a very complicated function of x, but for comparison with experiment it is not necessary to know $f(x)$ explicitly since all observable quantities can be expressed in terms of the surface impedance Z, defined as $4\pi/c$ times the ratio of the electric to the magnetic field strength at the surface of the metal. For $p = 1$ we find that

$$Z = \frac{4\pi\omega l}{ic^2} \frac{f(0)}{f'(0)} = \frac{8i\omega l}{c^2(1 + i\omega\tau)} \int_0^\infty \frac{dt}{t^3 + \frac{i\alpha}{(1 + i\omega\tau)^2}} \varkappa(t), \qquad (2)$$

where

$$\varkappa(t) = \frac{2}{t^3} \{ (1 + t^2) \tan^{-1} t - t \}.$$

The expression for $p = 0$ is more complicated, but the results differ only in detail from those obtained for $p = 1$.

For frequencies which are not too high, we have $\omega\tau \ll 1$, and the integral in (2) is then a function of the single parameter α. In this case equation (2) reduces to the classical expression $Z_{cl} = (\pi\omega l/c^2)\sqrt{(6/\alpha)}\,(1+i)$ when $\alpha \ll 1$, and to

$$Z_\infty = \frac{8\pi^{2/3}\omega l}{3\sqrt{3}\,.\,c^2\alpha^{1/3}} (1 + \sqrt{3}\, i) \qquad (3)$$

when $\alpha \gg 1$. (For $p = 0$, Z_∞ has 9/8 times the value (3).) For intermediate values of α, Z has been obtained by numerical evaluation of the integral in (2). From the definition of α, it follows that α is proportional to l^3 for a given metal and a given frequency. Hence Z varies as $l^{-1/3}$ in the classical case but is independent of l when $\alpha \gg 1$. This result is in agreement with Pippard's observations of the resistive part of Z at a wave-length of 25 cm., and represents the quantitative refinement of his theoretical interpretation in terms of an 'ineffectiveness concept'[1]. From a detailed comparison of the experimental and theoretical curves, it is possible to estimate the value of α and hence of the free path corresponding to any particular temperature. Thus for Pippard's mercury specimen we find that $\alpha = 1{,}550$ and $l = 8{\cdot}5 \times 10^{-4}$ cm. at $T = 3{\cdot}72°$ K.

Writing $Z = R + iX$, we have $R = X$ in the classical limit, while equation (3) shows that

$R = X/\sqrt{3}$ when $\alpha \gg 1$. X has not been measured directly, but Pippard[4] has obtained some indirect experimental evidence which indicates that X does, in fact, exceed R in the anomalous region.

The expression (2) has further been computed as a function of $\omega\tau$ for several values of the ratio $\alpha/\omega\tau$. ($\alpha/\omega\tau$ is independent of ω and, for a given metal, determines the value of l; the values chosen correspond to several temperatures between room temperature and liquid helium temperatures.) The ratios R/R_{cl} and X/X_{cl} are found to have the classical value unity for sufficiently low, and again for sufficiently high, frequencies (which are, however, well below the frequency for which the metal becomes transparent), and to pass through a maximum value at intermediate frequencies. The anomalous effects become less marked as the temperature increases, and have disappeared almost completely at room temperature. To give some idea of the orders of magnitude involved, choosing values of the parameters which correspond to a very pure specimen of silver at liquid helium temperatures, we find that R/R_{cl} attains a maximum value of 180 at a wave-length of 69 μ, while X/X_{cl} attains a maximum value of 5·3 at a wave-length of 7·6 cm. The absorption coefficient of the metal is increased in the same ratio as R; thus in the above example the theoretical absorption coefficient at 69 μ is $1{\cdot}44 \times 10^{-3}$, whereas the classical value is only 8×10^{-6}. Since the absorption is so small even in the anomalous case, an experimental verification of these predictions is likely to be very difficult.

A full account of the theory is to be published elsewhere.

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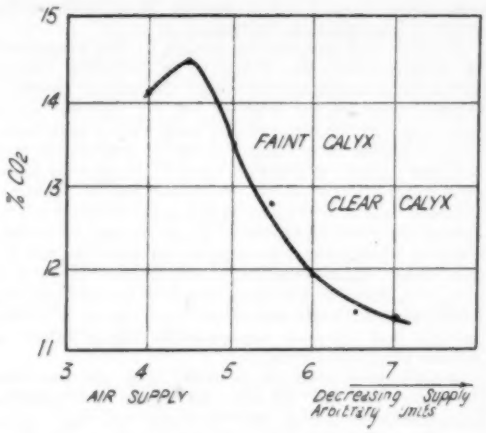
Use of 'Calyx' Burner to Determine Combustion Conditions

Brinsley and Stephens[1] have described an apparatus in which air and gas are pre-mixed and burned in a vessel from which the only exit is a small hole. When the proportion of air in a mixture originally air-rich is gradually reduced, the flame alters, and at one stage a violet sheath appears, surrounding the lower part of the flame. This sheath Brinsley and Stephens call a 'calyx'; they claim that it appears when the gas–air is that theoretically required for complete combustion.

It was thought that sampling the products of combustion as the theoretical mixture was burning would enable the maximum possible concentration of carbon dioxide in these products to be determined by a single analysis. This would be of service in testing gas appliances.

A mixture of coal gas and air was used. It was found that the flame is stable over only a small range of needle-valve settings: both the rate of supply of the mixture and its constitution have to be approximately correct or the flame goes out. Adjustment is not difficult once the operator has become familiar with the appearance of the flame in various circumstances, and the flame changes described by Brinsley and Stephens can then be readily observed.



Tests were made keeping the gas supply constant and cutting down the air in a series of arbitrary steps; at each setting a sample of the combustion products was taken and analysed for carbon dioxide. The results are shown in the accompanying graph. It will be seen that the calyx did not appear until after the maximum carbon dioxide concentration had been passed, and even then was only faintly visible. This reveals the chief objection to the use of the phenomenon for determination of theoretical combustion conditions. The calyx does not appear sufficiently suddenly; it 'fades in' as the air supply decreases, and the threshold visibility depends on the eyesight of the observer and on his experience. If it were used for determination of the maximum concentration of carbon dioxide in the combustion products, low results would be very probable.

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A New Sulpha Compound ("6257") and its Use in Human Cholera Infection

It was observed by one of us (S. S. B.) in 1939 that hexa-methylene-tetra-amine, in a 10 per cent solution in normal saline, killed cholera vibrio in less than half an hour up to a concentration of 10^{12}. Although interrupted by conditions of field service, efforts resulted in the production of three crude compounds of hexamine linkage to *para*-aminobenzene sulphonamide, experiments with which, on animal and human cholera infection, gave hope of successful chemotherapy against Asiatic cholera. A chance discussion with the scientific department of C.I.B.A. (Basle) resulted in our obtaining a condensation product—"6257"—of two molecules of 2 *p*-amino-benzene sulphonamido-thiazole ('Cibazol') and three molecules of formaldehyde with the formula $C_{21}H_{22}O_4N_6S_4$ (the actual constitution not having yet been worked out) and molar weight much greater

than that of any other sulpha compound so far employed in clinical therapy.

In vitro, the bactericidal action of this compound on cholera vibrio was found to be powerful. When one million organisms of either the strain Inaba or Ogawa were seeded into 10 ml. of peptone water (pH 8·0) and 50 mgm. of the drug added, suspended in gum arabic in 0·1 ml. volume, it was found that samples plated on alkaline agar, 6, 12 and 24 hours after incubation at 37° C., remained sterile. Further confirmation of this observation was obtained (*a*) by testing the total inoculum of 10 ml. by the pour-plate method, when there was complete absence of growth; and (*b*) by transferring the total inoculum, in portions of 0·1 ml. each, to a hundred tubes of glucose peptone water with Andrade indicator, the absence of visible growth and of acid fermentation being taken as indices of non-viability.

Where the concentration of the drug was less than 50 mgm. (40, 30, 20 and 10 mgm.) well-marked bacteriostatic action was evident on the initial inoculum of one million bacterial cells, as judged by colony counts and hæmocytometer readings in comparison to control tubes. With 5 mgm. of the drug there was no difference between the control and experimental tube readings.

In vivo experiments on mice further confirmed these results. Twenty mice were employed for each experiment. Separate sets of animals were given 50 mgm. and 40 mgm. of the drug by the intraperitoneal, the subcutaneous and the oral routes, in divided doses, for two days prior to the test dose. This was injected intraperitoneally and was kept in the region of 2 *M.L.D.* to exclude mortality by toxic action alone. The mice were thereafter given two doses of "6257", morning and evening, for four days only, and the mortality-rate was observed for fifteen days. 100 per cent protection was obtained by the intraperitoneal and the subcutaneous routes. By oral feeding, however, only 10 per cent of the animals were saved. Post-mortem examination of dead mice revealed that intraperitoneal cholera infection resulted in septicæmia, the vibrios being isolated from heart blood, liver and spleen. Poor absorption of the drug from the intestinal tract, as judged by low blood concentrations, was therefore responsible for the high mortality in this group.

Field trials were carried out in the Tanjore District of South India, where there were cases of Asiatic cholera in many villages. The patients were treated in their homes without any other medical aid, in co-operation with local health authorities. The great majority of cases were under-nourished women and children with purgation, vomiting, suppression of urine and concomitant symptomatology. A specimen of rice-water stool was obtained initially to establish the diagnosis bacteriologically. The drug was then administered in a dose of 6 gm. followed four hours later by another 4 gm., commonly by mouth; where it was not retained, it was given per rectum. Vomiting was invariably stopped and purgation much reduced within six hours; the flow of urine took place by the ninth hour. The alimentation was barley *kanji* with plenty of water, especially soda-water, wherever available, since it helped to re-establish the function of the kidneys. The total dosage was 28 gm., given as 10 gm. on the first day, two doses of 4 gm. on the second day, and two of 1 gm. each morning and evening every subsequent day for five days. Under this regime, cholera vibrios were absent from the stool on the fifth morning. Administration of the drug to other occupants of the hamlet protected them from becoming infected.

To date 85 cases of bacteriologically established Asiatic cholera in twenty-seven villages have been treated, with a case mortality of 4 per cent in contrast with an average mortality of more than 60 per cent during the past seven years. No toxic manifestations with a maximum dose of 50 gm. have been observed. Besides the curative effect of this simple form of therapy under conditions where the possibility of hospitalization and the availability of medical care is slender, its prophylactic and preventive aspects are emphasized.

Detailed investigations are being published elsewhere.

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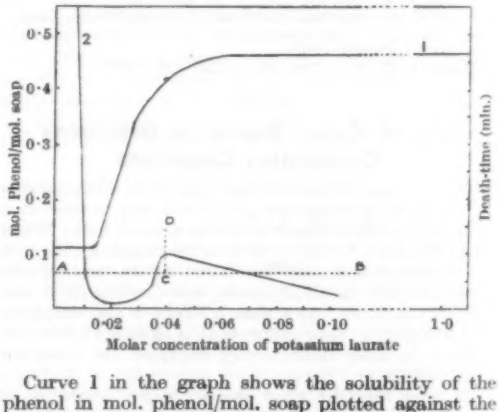
Bactericidal Activity of Phenols in Aqueous Solutions of Soap

Investigations begun in 1940 concerning the bactericidal action of phenols solubilized by aqueous soap solutions were interrupted during the War but resumed in 1946. Results with a water-insoluble phenol (5-chloro-2 hydroxy-diphenyl methane) using potassium laurate as the soap will be published shortly and have shown (*a*) that the solubilization of the phenol in the soap solution commences at the critical concentration for initial formation of micelles, and that the solubility curve is of the same form as that quoted for solubilization of water-insoluble dyes by soap solutions[1,2]; (*b*) that the bactericidal activity of the phenol soap solutions is a function of the concentration of the phenol in the micelles.



Curve 1 in the graph shows the solubility of the phenol in mol. phenol/mol. soap plotted against the molar soap concentration, and superimposed on it is Curve 2 representing the activity, in terms of the death-time of *B. coli*, at points along the line *AB* throughout which the ratio phenol/soap remains constant.

Below 0·01 *M* potassium laurate, the death-time decreases rapidly as the line is traversed in the direction of *B*, the concentration exponent over this range being of the order expected for an aqueous

solution of a phenol. At 0·01 *M* potassium laurate the slope of the death-time curve alters sharply, first flattening, then rising to a maximum at about 0·04 *M* potassium laurate and finally decreasing again with concentration. In the range 0·01–0·04 *M* potassium laurate, the amount of the phenol which the soap will solubilize increases rapidly; but as the phenol/soap ratio remains constant in the solutions used, the degree of saturation of the micellar material actually decreases from about 0·015 *M* to 0·04 *M*, and it is this fact that is responsible for the rise of death-time in this range. That activity is greatest at approximately 0·01 *M* soap is due to the concentration of phenol in the micelles being greater at this point than elsewhere along the line *AB*. Death-times along line *CD* decrease rapidly as the amount of phenol per molecule of soap increases, indicating that maximum bactericidal activity is attained where the micelles are fully saturated with the phenol.

Experiments using sparingly soluble phenols like 2-chloro-5 hydroxy-1 : 3-dimethylbenzene and water-soluble phenols such as the cresols are in progress, and results will be published in due course.

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Calcium-Deficient Media: Their Effect on Phage Action

While typing staphylococci by the bacteriophage method of Wilson and Atkinson[1], I encountered three batches of nutrient agar that were strongly inhibitory to phage action; several of the phage filtrates had to be used in a concentration one hundred times greater than normal.

Stassano and de Beaufort[2], Asheshov[3], Bordet[4], Burnet[5], and others have reported on the inhibitory effect of sodium citrate when added to media used for the demonstration of phage action. This suggested that a deficiency of calcium in the medium might be responsible for the inhibition of phage action referred to above. On the suggestion of Dr. G. P. Gladstone of the Lister Institute, calcium chloride in concentrations of *M*/100 were added to two of the batches of inhibitory media; the third was unfortunately discarded. The effect was striking. The media were now found to be completely satisfactory for the demonstration of bacteriophage activity.

As a result of this experience, it is considered advisable to add calcium chloride to solid culture media that are to be used for the typing of staphylococci by the bacteriophage method.

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Production of Itaconic Acid and Kojic Acid by a Species of *Aspergillus*

The observation reported in the present note relates to an *Aspergillus* with yellow- to ochraceous-coloured conidia. The mould does not appear to correspond entirely with any published description.

Grown upon the surface of a 20–25 per cent sucrose solution containing the nutrient salts of Kardo-Ssyssojewa's medium[1] at 28° C. in the presence of calcium carbonate, this mould produces both itaconic acid and kojic acid. The relative proportions in which the two compounds appear may be varied by varying the conditions of the fermentation. At higher temperatures itaconic acid preponderates and may amount to more than 20 per cent of the weight of the sugar provided.

The itaconic acid was prepared from the calcium salt which is present in solution and often also separates as nodules on the underside of the mould. Its crystals showed characteristic cleavage; m.p. 163–166° C., not altered by admixture with authentic itaconic acid; analysis: C, 46·41, 46·53; H, 4·92, 5·00 per cent (calc. for $C_5H_6O_4$: C, 46·15; H, 4·61 per cent); equivalent, 65; the calcium content of the calcium salt was 21·5 per cent.

The kojic acid was prepared *via* the insoluble copper salt. It melted at 152–153° C.; its solution gave an intense blood-red colour with ferric chloride.

Itaconic acid has hitherto been shown to be produced by *A. itaconicus*[2] and by *A. terreus*[3]. The itaconic acid fermentation by *A. terreus* has since been extensively investigated in the United States in the Fermentation Division of the Northern Regional Research Laboratory[4–7].

The work now reported is being continued, and it is hoped to publish it fully elsewhere in due course.

It is a pleasure to acknowledge the assistance of my colleague Mr. J. H. Morrison and of a former colleague, Mr. C. W. Hutchinson.

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[1] Kardo-Syssojewa, H., *Z. Bakt.*, **93**, 265 (1936).
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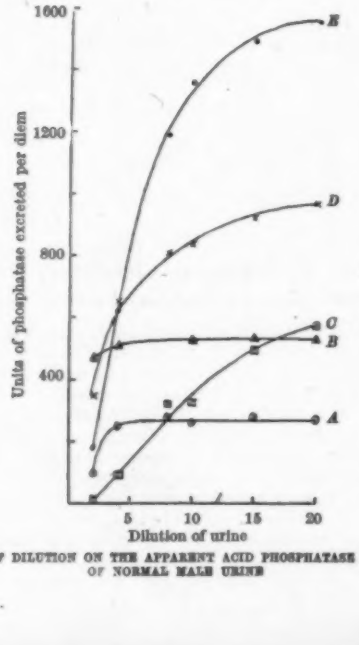
Presence of Substances Inhibitory to Acid Phosphatase in Normal Human Urine

In adult bilateral cryptorchid human subjects, a correlation has been found between androgen excretion in the urine and the amount of acid phosphatase in the semen[1]. The suggestion was made that if a similar correlation was found in normal subjects, measurement of acid phosphatase in semen might suffice for appraisal of urinary androgen content. Since specimens of urine are usually more easily obtained than those of semen, it seemed to be worth while to determine whether a correlation exists between urinary androgens and urinary acid phosphatase.

Recently Burgen[2] has described a method for the estimation of the urinary excretion of acid phosphatase, and his results on normal human subjects were a further indication that some correlation might exist between the daily excretion of this enzyme and that of 17-ketosteroids. It was found that the level of excretion of acid phosphatase is low in male children, but that from puberty onwards there is a sharp increase reaching a maximum in the fourth decade and then falling off in old age. Such a distribution resembles the known distribution of 17-ketosteroids with age in male subjects.

Experiments were therefore undertaken to compare the daily output of urinary acid phosphatase and urinary 17-ketosteroids by normal male subjects. The ketosteroid estimations were carried out by a standard colorimetric procedure and the acid phosphatase measurements were made, at least initially, by the method described by Burgen[2].

Difficulty in the estimation of the enzyme was encountered when some rather concentrated urines (daily volumes less than 700 ml.) were used. In Burgen's procedure the urine is prepared for assay by preliminary dilution with an equal volume of water. In order to reduce the blank values of these concentrated urines, higher dilutions were employed, and it was found that in some cases the amount of enzyme apparently increased with increasing dilution. In some urines the apparent amount of enzyme was still increasing at the limit of dilution in which it was practicable to estimate it. In other urines the amount of enzyme increased to a maximum after slight dilution of the urine, and then maintained a constant value to the limit of measurement. Urine from the same subject showed different behaviour with respect to this dilution effect on different occasions. Representative curves for five different urines are reproduced herewith. The daily output of acid phosphatase as computed from measurements of the enzyme on urine specimens initially diluted from two to twenty-fold is plotted against the dilution employed. It is clear that a reliable estimate of the urinary acid phosphatase can be obtained only on urines that show constant values on dilution (Curves *A* and *B*). In other cases no one value can be taken as a true measure of the enzyme content (Curves *C*, *D*, and *E*).



EFFECT OF DILUTION ON THE APPARENT ACID PHOSPHATASE CONTENT OF NORMAL MALE URINE

The most likely explanation of these results appears to be the presence in urine of one or more substances inhibitory to acid phosphatase. The variation in the dilution effect shown by different urines would then be due to the presence of different amounts of the inhibitory substance. Investigations on this point are now in progress. Until such inhibitors can be identified and eliminated from urine, it would appear that values for urinary acid phosphatase based on measurements at one dilution only must be regarded as provisional.

We should like to thank Dr. A. S. V. Burgen for helpful discussion and for showing us some of his unpublished results.

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Trace Elements and Nitrification

THE exact requirements of the nitrifying bacteria for inorganic nutrients are not yet known, though all workers on this group since Winogradsky[1] have assumed that they require iron, and many workers have added traces of other metals to their media[2], or used tap-water as a diluent, because of the possible trace elements it contains[3]. One of us has recently discovered[4], by the percolation method[5], that copper is apparently essential for nitrification in soil, so we decided to try the effect of iron and copper, alone and with other trace elements, on nitrite formation in cultures of nitrifying bacteria.

The cultures were grown at 25° C. in shallow layers of the following *liquid* medium: *M*/200 sodium chloride, *M*/1,000 magnesium sulphate, *M*/1,000 potassium dihydrogen phosphate, *M*/200 ammonium sulphate, dissolved in glass-distilled water, with 1 gm. calcium carbonate added to every 100 ml. They were not pure cultures, but must have contained a large population of nitrifying bacteria, as rapid and complete nitrification took place in them, the ammonia in the medium being converted first to nitrite and then to nitrate. The *inoculum* in the first experiment was taken from an active culture, the fourth transfer of a series in liquid media. The parent culture was obtained by incubating a small quantity of Rothamsted soil in Winogradsky's medium[1]; two serial transfers were later made to Winogradsky's medium, and two to the more dilute liquid medium described above. The *volume* of inoculum in the first experiment was only 8 drops to 100 ml. of medium; as nitrite formation was delayed in this case, the volume of inoculum was increased to 1 ml. in the other experiments, which were inoculated in each case from one of the control flasks of the previous experiment.

Salts of iron, zinc and copper were added to the medium to give the following quantities: iron

600 μgm., zinc 13 μgm., copper 14 μgm. per 100 ml. In the first experiment only, copper was added to two flasks at the rate of 28 μgm. per 100 ml. Nitrite was estimated colorimetrically with the Griess–Ilosvay reagent[5]; each figure is the mean of determinations on duplicate cultures.

Treatment	Experiment 1 11 days incubation Nitrite mgm. N/l.	% of control	Experiment 2 5 days incubation Nitrite mgm. N/l.	% of control	7 days incubation Nitrite mgm. N/l.	% of control
Control	18	100	18·5	100	99	100
Iron	28	156	31·5	170	114	115
Copper 14 μgm.	21	117	27·5	149	80	81
Copper 28 μgm.	21	117	—	—	—	—
Iron + copper	34·5	192	22·5	122	94	95
Iron, copper and zinc	36·5	203	33·5	181	110	111

In a second pair of experiments the same three metals were added, together with a trace-element solution[6], supplying lithium, boron, aluminium, tin, manganese, nickel, cobalt, titanium, iodine and bromine. Iron was included in the medium in one experiment, and omitted in the other.

Experiment 3 Treatment	11 days incubation Nitrite mgm. N/l.	% of control	Experiment 4 Treatment	10 days incubation Nitrite mgm. N/l.	% of control
Control	41	100			
			Iron only	125	305
Trace elements only	20	49	Iron + trace elements	44	108
Trace elements + zinc	22	54	Iron, trace elements, zinc	45	110
Trace elements + copper	39	95	Iron, trace elements, copper	94	230
Trace elements, copper, zinc	34	83	Iron, trace elements, copper, zinc	99	241

The requirements of the nitrifying bacteria for elements such as iron and copper must be extremely small, as nitrite was formed in the control cultures, which must have contained the merest accidental traces of any of them. Also, as the medium contained an excess of calcium carbonate, only a very small proportion of the heavy metals added can have been in solution, and it is impossible to tell how much of the added elements were actually available to the bacteria. The outstanding feature of these results is the stimulating effect of iron; while mixtures of iron and copper, or iron, copper and zinc, had no more effect than iron alone. The unbalanced mixture of trace elements had an inhibiting effect on nitrite formation, which was not removed by zinc, but was removed by iron or copper. But the trace-element mixture with iron and copper, or iron, copper and zinc, had a stimulating effect. It appears probable that a proper balance of inorganic nutrients is more important for nitrification than the quantity of any one nutrient available.

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Vascular Patterns in the Testis, with Particular Reference to *Macropus*

IN the course of a comparative study of the vascular supply of the testis in mammals, a remarkable variety of patterns of the testicular artery in the spermatic cord and on the free surface of the organ has been revealed by radiography after the injection of colloidal bismuth and 'Wettal'[1]. Some of these findings are in agreement with those of earlier workers[2–6].

In all animals so far examined, except man and the wallaby, the testicular artery before reaching the testis undergoes a tortuous convolution. On reaching the testis, it does not pass into it at the mediastinum (as commonly stated in text-books), but ramifies over the free surface of the gland on the deep aspect of the tunica albuginea in a variable pattern. Thus, in the rabbit, the white-spotted squirrel and Bosman's potto (*Perodicticus potto*), the artery may encircle the gland two or three times before giving off any branches to the testis parenchyma, while in the rat, porcupine, ram, bull and rhesus monkey it describes a series of zig-zagging convolutions on the surface of the testis before supplying the gland.

The most interesting pattern in the spermatic cord and on the testis is, however, seen in the wallaby, *Macropus rufogrisea fruticus*. The single artery, near the testis, divides into no less than ninety-six separate branches which pass down to the organ without anastomosing (Fig. 1), to reach the mediastinum and then join again to form three to four vessels which ramify over the posterior surface of the testis in arborizing fashion. The veins are collected in a similar pattern from the anterior surface of the testis and pass over the superior pole to collect at the mediastinum. From here a pampiniform plexus of about a hundred veins passes up the spermatic cord. In the transverse section of the cord shown in Fig. 2 (× 9) the numerous branches of the testicular artery, containing colloidal bismuth injection, are seen intermingled with the veins of the pampiniform plexus. This remarkable branching of the testicular artery to form a sort of 'rete mirabile' may possibly be a marsupial characteristic; but further material will need to be examined before this can be determined.

Despite the diversity of pattern of the testicular artery in the spermatic cord and on the testis in

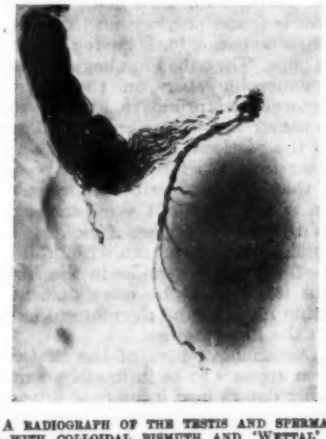

Fig. 1. A RADIOGRAPH OF THE TESTIS AND SPERMATIC CORD INJECTED WITH COLLOIDAL BISMUTH AND 'WETTAL' THROUGH THE TESTICULAR ARTERY BEFORE DIVISION. NATURAL SIZE

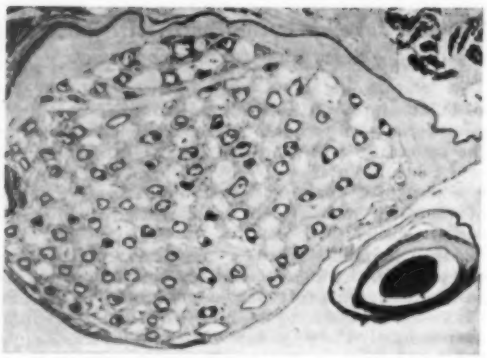

Fig. 2. TRANSVERSE SECTION OF THE SPERMATIC CORD. × 9

different mammals, it seems that the different arrangements possibly have a common functional significance, namely, to provide a mechanism for the exchange of heat in the temperature control of the testis. Experiments to test this inference are now being undertaken.

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Relationships in the Plumbaginaceæ

POLLEN- and associated stigma-dimorphism within the family Plumbaginaceæ were discovered in 1883 by McCleod[1], who observed them in *Limonium*. Since then, the range of genera showing pollen-dimorphism has been extended by various authors[2–5] to include *Armeria*, *Acantholimon* and *Limoniastrum*, while stigma-dimorphism has also been demonstrated in *Armeria*[3,4].

I have made a survey of all genera within the family and have established that the clear pollen-dimorphism is found only within the tribe Staticeæ, where there is no reason for believing that it has arisen more than once. The tribe Plumbagineæ contains only pollen-monomorphic genera, and there is evidence that this monomorphism is primitive. Extreme modification in embryo-sac structure is typical of the Plumbagineæ[6] but not of the Staticeæ, so that the direct derivation of the latter from the former is not possible. It is probable that the two tribes represent diverging lines from a common (but very ancient) ancestral stock. Within the Staticeæ, *Ægialitis* is unique in showing pollen-monomorphism with grains which are probably of the same type as in the Plumbagineæ. This genus is likely to be more ancient than any others within its tribe and therefore to have diverged least from the Plumbagineæ.

In the remaining genera of the Staticeæ, pollen-dimorphism appears to be intimately connected with a genetically determined incompatibility mechanism. Derived monomorphism, however, occurs in *Limonium* and *Armeria* at least and appears to be connected, here, with self-compatibility, which may be of use in regions where pollinating insects are sparsely represented and also in facilitating establishment after long-distance dispersal.

Heterostyly occurs in *Limonium*[7], and in the Plumbagineæ[7,8], but there is some slight evidence that the development of the incompatibility mechanism made visible by pollen- and stigma-dimorphism has preceded heterostyly in the Staticeæ. If this be true, heterostyly in the two tribes would have resulted from parallel evolution.

The detailed results of these and other studies within the family will be published elsewhere in a series of papers, but this further extension of the use of pollen-morphology to indicate relationships is possibly of general interest.

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Pharmacology of Ch'ang Shan (*Dichroa febrifuga*), a Chinese Antimalarial Herb

FOR centuries in China the roots (Ch'ang Shan) and the leaves (Shuu Chi) of *Dichroa febrifuga*, Lour. have been used against malarial fevers. In our first report[1] in 1943, it was recorded that a crude extract of this root had been effectively used on clinical cases of tertian malaria. Then in 1945, when *Plasmodium gallinaceum* became available to us, we found that the crude extracts of both the root and the leaves of the herb were also effective for chicks infected with *P. gallinaceum*, the leaves being about five times as active as the roots. An alkaloidal fraction of the root exhibited a marked anti-malarial activity, but of the three alkaloids, *F* (later called dichroine *A*), *G* and *I*, and two neutral principles, *E* (later dichrin *A*) and *H* (later dichrin *B*), none was found active[2]. In the following year we announced the isolation of an active alkaloid, dichroine *B*, melting at 237–238° C. with decomposition (considered as hydrochloride at first, later identified as dihydrochloride). It was effective against chicken malaria in intramuscular doses of 2–4 mgm./kgm. twice or thrice a day[3]. The empirical formula of dichroine *B* was first reported as $C_{16}H_{19}O_2N_3$ [4], and later as $C_{16}H_{21}O_2N_3$ when purer batches were examined[5]. As reported to the general conference of the Chinese Physiological Society on May 14, 1947, we had thus far isolated from Ch'ang Shan altogether five alkaloids and two neutral principles. Among the five alkaloids, dichroine *A*, dichroine *B*, dichroine *C*, dichroidine and quinazolone (4-keto-dihydroquinazoline), the first three members were soon found to be isomers mutually convertible under certain conditions. In conformity with the conventional nomenclature of isomers, they have been, thenceforth, called dichroine-α, dichroine-β, and dichroine-γ respectively[5]. With the probable exception of dichroine-α, all these alkaloids are more or less effective against *P. gallinaceum* infection in chicks, their antimalarial activity being in the

descending order as follows: dichroine-γ, dichroine-β, dichroidine and quinazolone. From analytical studies of the oxidation products of dichroine-α, it is apparent that the dichroine isomers are quinazoline derivatives. Of the two neutral principles, dichrin *A* and dichrin *B*, the first has been identified as umbelliferone. In the accompanying table, the chemical and pharmacological properties of these seven substances from *Dichroa febrifuga* are summarized.

Principle	Formula	M.p.	*L.D.*50, mice. I.V. (mgm./kgm.)	Antimalarial activity, *P. gallinaceum*, (mgm./kgm.)
Dichroine-α	$C_{16}H_{21}O_3N_3$	136	18·5	Ineffective up to 8 mgm.
Sulphate		230*†		
Hydrochloride		210†		
Dichroine-β	,,	146	4·6	4
Hydrochloride		219†		
Dihydrochloride		238†		
Sulphate		224†		
Dichroine-γ	,,	161	5·0	1
Hydrochloride		219†		
Dihydrochloride		238†		
Sulphate		224†		
Dichroidine	$C_{15}H_{22}O_2N_2$	213		Effective 40
Quinazolone	$C_8H_6ON_2$	212		
Hydrochloride		250		
Dichrin *A* (Umbelliferone)		228–230		Ineffective up to 4 mgm.
Dichrin *B*		179–181		Ineffective up to 4 mgm.

* Crystallizing from water. † Melting with decomposition.

We also wish to state that another Chinese herb, Tou Ch'ang Shan, exhibits potent antimalarial action on chicken malaria. This herb has been tentatively identified as *Hydrangea umbellata*, Rheder., belonging to the same family (Saxifragacea) as *Dichroa febrifuga*. Its active fraction has been found to be also alkaloidal in nature, and several crystalline alkaloids have been isolated.

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Three further references to work on *Dichroa febrifuga* can be added to those quoted above: they are Tonkin and Work, *Nature*, **156**, 630 (1945); Cheng Fang Tsu, *J. Trop. Med. and Hyg.*, 75 (April, 1947); and J. B. Koepfli, J. F. Mead and J. A. Brockman, *J. Amer. Chem. Soc.*, **69**, 1837 (1947). Dr. Koepfli refers to the earlier work of Dr. Jang and directs attention to the disparity in melting point between his own and Dr. Jang's active alkaloid. The new results now presented by Dr. Jang do not resolve this difficulty. Dr. Koepfli suggests, however, that, at any rate in leaf, the biological activity is not accounted for by the active alkaloid which he isolated; thus several related bases may be present. It should also be noted that Dr. Koepfli suggested the active principle was a quinazoline derivative, a conclusion which is now reached by Dr. Jang also.

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Annealing of Glass

It is well known that the relaxation of stress in glass during annealing does not follow the Maxwellian relaxation formula. Indeed, annealing schedules for glass are always based on Adams and Williamson's[1] empirical law that the reciprocal of the stress is proportional to the time. Littleton[2] and Lillie[3] have attempted to account for the discrepancy on the basis of the viscosity being a function of the time, and many workers have attributed it to the dependence of the stress relaxation on some 'molecular viscosity' or upon changes in the equilibrium state of the glass.

If the change in the state of glass associated with temperatures about and above the annealing range is pictured as the development of 'holes' (or the equivalent concept, the development of two-positioned sites for some of the ions[4]) with increasing temperature, one can express the number of such holes as a function of temperature and pressure for equilibrium, and, by a treatment similar to that used in calculating the rates of crystal growth[5], one can find the rate of approach to equilibrium. Thus an equation for the stress relaxation may be derived:

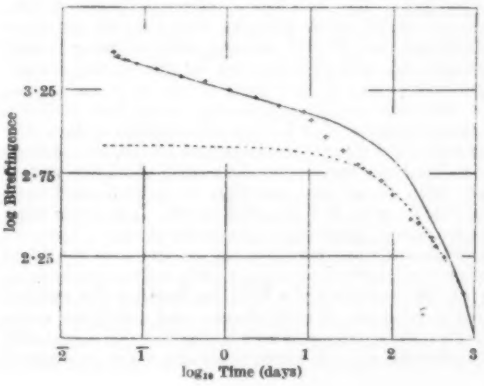
$$\log S_0/S = at + b \log \{1 + D(1 - \text{expt.-wt.})\}.$$

At low temperature (430° C.) 'W' is very small, so that provided the time is not too long:

$$\log S_0/S = at + b \log (1 + ct),$$

where S_0 and S are the initial and subsequent stresses and t is the time.

In this expression the constant a is inversely proportional to the viscosity, and no allowance is made



for variation of viscosity with time, although such is to be expected because of the changing state of the glass. While the first term on the right-hand side has a form similar to Maxwell's relaxation, the constant a differs from his expression rigidity/viscosity by virtue of the 'hunting' action of the pressure-sensitive equilibrium upon the stress.

Morey's[4] experimental results for 'Pyrex' chemical resistance glass at 430° C., which extended over two years, are shown in the graph, where both stress (birefringence) and time are plotted as logarithms. The full curve is calculated from the expression above, while the stress calculated from the empirical law according to Adams and Williamson is dotted.

Inspection will show that the departure of the continuous line from the observed values is such as would be expected from neglect of viscosity variation.

Adams and Williamson's law holds only over a small part of the total time range, and is therefore of little theoretical significance. Its value lies in that it holds over just that range of time which is of practical importance.

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Determination of Silicate Inclusions in Steel

The appearance of non-metallic inclusions and their influence on the mechanical and corrosion properties of steel have been the subject of many investigations[1,2]. For the determination of silicate inclusions, many methods (chlorine, bromine, iodine and electrolytic) have been used successfully. But they are all rather difficult; other simpler methods, such as the dissolution of the steel sample in nitric, hydrochloric or sulphuric acids, give uncertain results. In the search for a simple method, we used the dissolution of steel in acetic acid.

The treatment worked out by us is in outline as follows: 20 gm. very fine drillings of unhardened steel (hardened steel gives results which are too high on account of the adsorption of silicic acid on carbon) are put into 500 c.c. of 2 *N* acetic acid in an Erlenmayer flask. The flask has a stopper with two tubes, through one of which nitrogen is introduced (or other indifferent gas) free of oxygen; the nitrogen passes through the acid and escapes by the second outlet. The flask is put on a boiling water bath and, when the drillings are dissolved (for very fine drillings it takes three to four hours), the solution is decanted through a fine filter (Schleicher and Schüll, Blau Band) in a Buchner funnel, washed with distilled water, then with 3 per cent solution of sodium carbonate and finally with hot distilled water. The filter with the residue is ignited in a platinum crucible. Then we determine silicon dioxide in the ash in one of the usual ways; or (1) after melting it with sodium carbonate, or (2) by expelling the SiO_2 by heating the residue with a mixture of hydrofluoric and sulphuric acids after previous treatment of the residue with a mixture of hydrochloric and nitric acids (in order to remove the greater part of iron oxides). In the remaining oxides we can determine the Al_2O_3 content of the steel.

To test the method we determined the SiO_2 content of seven steels, the compositions of which are shown in Table 1.

Table 1. Composition of steels (per cent)

Number of steel	C	Si	Mn	P	S
1	0·14	0·14	0·46	0·014	0·028
2	0·40	0·35	0·60	0·021	0·010
3	0·46	0·30	0·62	0·021	0·026
4	0·57	0·24	0·57	0·033	0·042
5	0·65	0·30	0·70	0·037	0·026
6	0·98	0·16	0·32	0·024	0·010
7	1·09	0·29	0·19	—	0·008

In Table 2 are summarized the results of determinations of SiO_2 by the chlorine, bromine, electrolytic (Benedicks – Skapski) and the method described above. The results of the chlorine, bromine and electrolytic methods are average results.

Table 2. Percentage of SiO_2 in steels

Number of steel	Chlorine method	Bromine method	Electrolytic method	Acetic method	Mean
1	0·021	0·019	0·0185	0·020 0·018 0·020	0·0193
2	0·0115	0·015	0·0097	0·012 0·010 0·009	0·0103
3	0·0055	0·0055	0·005	0·005 0·006 0·004	0·0050
4	—	0·007	0·006	0·008 0·006 0·006	0·0067
5	—	0·0105	0·014	0·013 0·012 0·013	0·0127
6	0·005	0·008	0·0085	0·008 0·008 0·007	0·0075
7	0·0023	0·0032	0·00325	0·007 0·0030 0·0029 0·0032	0·00303

The agreement of the results obtained by the new method with those by generally accepted methods is quite satisfactory. The determination of the Al_2O_3 content in steel gives good results, too, in comparison with the results obtained by the dissolution in nitric acid or electrolytic dissolution.

A detailed description of the method will be published in the near future.

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Extinction of Petrol Fires by Methyl Iodide

The distressing and increasingly frequent incidence of fatal fires in tankers, aeroplanes and other petrol-using machines, and in factories and laboratories employing fuels and inflammable solvents, has repeatedly directed attention to the need for a quick quenching agent. In such straits, so long as they

contain carbon tetrachloride, the brass squirts so universally carried are of less use than mascots. This substance will not extinguish petrol fires. At best, it may localize the combustion. It yields stifling clouds of black soot and twice its own vapour-volume of chlorine. It is itself toxic.

As a young man, I worked as an assistant both to R. V. Wheeler and to H. B. Dixon, and it has occurred to me to follow up the latter's investigation of the former's discovery of the combustion-inhibiting influence of the iodides. One of many reasons for the choice of methyl iodide for the initial experiments was its physical resemblance to carbon tetrachloride. Chemically and physiologically it is very different. It is safer and pleasanter in use; and it does not yield noxious or corrosive end-products.

It was found that in all cases where carbon tetrachloride was effective, methyl iodide was equally effective with one fifth of the quantity. Both were better sprayed than squirted, and the pumps and syringes needed non-greasy lubrication. The crucial experiment was then tried of spraying it on to a water-borne layer of petrol on fire. Up to forty square feet, garden syringes were used. Over greater areas a pump was desirable. This test gave a complete failure to carbon tetrachloride, a saturated water solution of ammonium iodide and to methylene di-iodide. These substances burnt in the flames. Under a spray of methyl iodide, however, the petrol flames broke, wilted and withered. There was no smothering or swamping; the effect resembled that of a policeman's hand on traffic. Moreover, the petrol can at will be repeatedly rekindled and re-quenched until it is made safe or exhausted.

Tray-fires of ether, methylated spirits, and white spirit, which could not be extinguished by carbon tetrachloride, were swiftly quelled by methyl iodide.

Some hundreds of comparisons made, less picturesquely, with a flash-point apparatus contain no single exception to this overwhelming superiority of methyl iodide.

This fact has immense possibilities in social consequences—the price, of course, must fall just as the price of *D.D.T.* fell. What it amounts to in physical chemistry seems to be a fascinating example of how combustion-chains may be affected by iodine atoms freshly liberated from a single valency. The iodine liberated in the burning of methylene di-iodide would clearly seem to have a different mode of existence.

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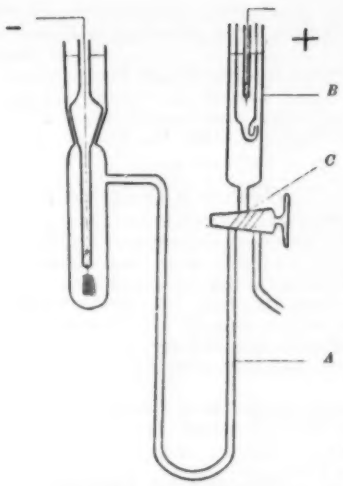
A Simple Moving-Boundary Apparatus

In the conventional types of apparatus for the measurement of transference numbers in electrolyte solutions by the moving-boundary method, elaborate devices are used to achieve the initial formation of a reasonably sharp boundary[1,2]. It seems surprisingly to have escaped notice so far that a sharp 'sheared' boundary can be formed satisfactorily and with less trouble by the use of a single three-way tap of good quality.

The apparatus used by us, illustrated in the accompanying figure, has been designed for the measurement of the transference number of hydrogen ion in hydrochloric acid solutions by a descending boundary in the tube *A*, using lithium chloride as the



'indicator' electrolyte. The adaptation of the principle to other measurements is obvious.

The whole apparatus is first filled with the hydrochloric acid solution with the tap in the position connecting *A* and *B*, after which the anode vessel is emptied (by turning the tap through 180°). *B* can then be rinsed through with the indicator solution at leisure. After turning the tap through 90°, *B* is filled with the indicator solution and, on connecting *A* and *B* again by turning the tap to the initial position, a sharp boundary is formed at *C* the velocity of which may be measured after it has passed through the tap.

We wish to thank Messrs. E. C. A. Horner and A. D. Jenkins for experimental assistance.

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[1] MacInnes and Longsworth, *Chem. Rev.*, **11**, 179 (1932) (review of then existing types).
[2] Hartley and Donaldson, *Trans. Farad. Soc.*, **33**, 458 (1937).

Elminius modestus in the Netherlands

Recently, Jones[1] remarked that the barnacle *Elminius modestus* Darwin, if introduced into France and Holland, is likely to become particularly troublesome for the oyster culture industry. It may be worth while to state that the species seems to be already fairly common in the southern part of the North Sea coast of the Netherlands.

As Bishop[2] stated that the barnacle was taken from the hull of the M.V. *Empire Wansbeck*, which had been plying between Harwich and the Hook of Holland, the species might be expected here. To direct attention to its probable occurrence, a note giving particulars of the barnacle was inserted in a stencilled periodical devoted to the study of the seashore, and the Leyden Museum soon received material of *Elminius* from Scheveningen and its surroundings and from Serooskerke in Zeeland. The first specimens on flotsam were collected on September 19, 1946; the first specimens on piles were obtained on October

18, 1947. The latter, therefore, undoubtedly have developed from larvæ occurring in Dutch waters.

H. Boschma

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[1] Jones, E. W. Knight, *Nature*, **161**, 202 (1948).
[2] Bishop, M. W. H., *Nature*, **159**, 501 (1947).

What is a Dialysate ?

In *Nature* of November 22, 1947, p. 720, H. G. Derx has commented upon the confusion caused by the lack of a suitable name for the material retained by a dialysing membrane. He has proposed the use of the term 'residue'. We have found the term 'impermeate', coined by Dr. Howard Eder in our laboratories some years ago, a very descriptive and helpful one to apply to such material

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Operational Research

In spite of the frequency with which operational research has been referred to recently, there are extremely few published discussions from which the layman can obtain an idea of what it is[1]. Its nature is actually extremely straightforward; the very simplicity of the basic idea is probably one of the reasons why many people seem to find it so difficult to grasp. In the first place, operational research is research in the true sense. I would refer to Blackett's obituary notice of E. J. Williams[2], in which he tells how Williams found the phenomena of U-boat warfare as intellectually enthralling as those of atomic physics; and Williams could scarcely have been accused of not knowing what scientific research really means. The adjective 'operational' does not mean that the activity is not true research, any more than do the adjectives in such expressions as 'chemical research', 'genetical research', etc. It characterizes, not the quality of the research, but its subject-matter, which was originally the operations of armed forces. In a wider definition, operational research can be described as the application of the methods of scientific research to the study of the problems which face an executive authority.

The special characteristic which differentiates operational research from other branches of applied science is that it takes as the phenomenon to be studied the whole executive problem and not the individual technical parts; its interest may be focused, for example, on 'how to find U-boats from aircraft', while specialist applied sciences would be studying component parts of the situation, such as the physics of radar, the psycho-physiology of fatigue, etc. It is, perhaps, because operational research scientific workers had to depend so largely for detailed information on the generous collaboration of their specialist colleagues that some people appear to think that they invented new techniques of team-work. How badly the world needs such techniques! But it is for the sociologists, not the operational research workers, to discover them.

In point of fact, operational research possesses no new or special technique of its own. It uses the normal methods of scientific research to discover the facts about the phenomena which it is studying. Naturally, some of science's armoury of methods are more appropriate to its subject-matter than are others, just as genetical research often calls for statistical methods, while experimental embryology finds more use for manipulative skill. But it has no secret weapon.

Why, then, it may be asked, is it important to consider whether sufficient use is being made of operational research during peace? The answer, I think, is that although the methods of operational research are not new, the direct application of those methods to executive problems had only been made very spasmodically before the War, and, when undertaken on a reasonably large scale, proved itself to be extremely fruitful. The Services, which, on the fighting side, have an organisation designed for the specific purpose of deciding what to do and then doing it, soon recognized the difference between analysing the situation (operational research), drawing up a scheme to cope with it (planning) and putting the scheme into effect (operations), and possessed a framework into which the first of these could easily be fitted. The civil branches of government, which have only recently been called upon to initiate and carry out major enterprises, seem to find these distinctions more difficult to grasp; and we find *Nature* implying that operational research is a method of planning[3]. Research by itself can never produce a plan; its function is to prepare the basis on which a rational plan can be founded, by identifying qualitatively the factors in the situation, and, as far as possible, by evaluating them quantitatively. It seems to me astonishing that any scientific worker should doubt that the scientific method is by far the most powerful instrument we have for performing the analysis and fact-finding on which executive decisions should be based. Surely no one could be satisfied to try to "re-deploy the scientific effort of Great Britain" without trying first to find what the probable demands are in the various fields; what the available resources are, and would become; how many men of science could function equally well if re-directed into other fields; for what reasons scientific workers have taken up the work they are now doing; what the demands on teaching establishments would be to achieve different rates of re-deployment; and so on. Investigations of this nature, which would take into account all the factors which could be shown, or surmised, to influence the situation, would be equally necessary whether the planners eventually decided to put their schemes into effect by a totalitarian *fiat*, or by any of the gamut of subtler systems of payments and incentives. A beginning should be made with them, even though one believes that the brute facts, like Archimedes' tortoise, can never be completely overtaken by scientific analysis. But it only obscures the issue if consideration of the importance of research on behalf of the executive planners is prejudiced by opinions as to the method by which the plan should be put into operation.

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University of Edinburgh. Jan. 15.

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[As Prof. Waddington remarks, there have been few widely available accounts of operational research. The article by Sir Charles Goodeve on p. 377 will help to clarify the situation. Editors.]

A FACTOR IN HEART MUSCLE REQUIRED FOR THE REDUCTION OF CYTOCHROME *c* BY CYTOCHROME *b*

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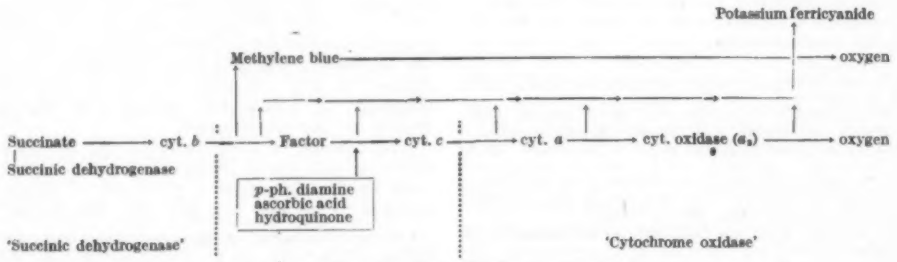
IT is well established[1] that the intracellular respiratory complex catalysing the aerobic oxidation of succinate (the succinic oxidase system) includes the cytochrome system in addition to the specific enzyme responsible for the activation of succinate (that is, succinic dehydrogenase). Thus the transport of electrons from succinate to molecular oxygen proceeds through a chain of electron carriers of successively higher oxidation-reduction potential[2]. Four such carriers have been identified spectroscopically, namely, cytochromes *b*, *c*, *a* and a_3. Cytochrome a_3 is probably identical with cytochrome oxidase[3]. The purpose of the present communication is to present evidence for the existence of an additional carrier. This evidence was obtained by studying the mechanism of the action of certain reducing agents (particularly the dithiol 2,3 dimercaptopropanol (*B.A.L.*)) on the succinic oxidase system of heart muscle.

It was found that the oxidation of this dithiol by air at *p*H 7·1 was catalysed by the heart-muscle preparation of Keilin and Hartree[1]. Treatment of the heart-muscle preparation with *B.A.L.*, in the presence of air, had two quite distinct effects on the enzymes responsible for the oxidation of succinate: (*a*) Complete inactivation of the succinic oxidase system (measured by the rate of oxidation of succinate in the presence of excess cytochrome *c*), without any effect on the succinic dehydrogenase (measured by the rate of oxidation of succinate in the presence of methylene blue and potassium cyanide); this inactivation is complete soon after the addition of the *B.A.L.* (*b*) A partial inhibition of succinic dehydrogenase, which does not occur until more than half the *B.A.L.* is oxidized; this inhibition is probably largely due to the action of oxidized *B.A.L.* on the sulphydryl groups of succinic dehydrogenase (cf. Hopkins and Morgan[4]). Incidentally, these observations reconcile the apparently divergent findings of Barron *et al.*[5] and of Webb and van Heyningen[6] on the action of *B.A.L.* on the succinic oxidase system, since the former workers measured the effect on the complete succinic oxidase system, whereas the latter studied the effect on the succinic dehydrogenase alone.

The inactivation of the complete system without concomitant inhibition of succinic dehydrogenase was produced only if *B.A.L.* was oxidized in air in the presence of the enzyme. No inhibition resulted from contact with the dithiol under anaerobic conditions, while oxidized *B.A.L.* only slightly inhibited the succinic oxidase system and at the same time inhibited succinic dehydrogenase. Although it was found that hydrogen peroxide was produced during the oxidation of the *B.A.L.*, the effect on the enzyme was not due non-specifically to this hydrogen peroxide, since hydrogen peroxide produced by other systems (notatin-glucose; *d*-amino-acid oxidase and its substrates) inactivated the enzyme only partially, and this inactivation, but not the *B.A.L.*-induced inactivation, could be partly protected by alcohol and by pyruvate and was increased by catalase. Moreover, the addition of copper, which increased the rate of oxidation of *B.A.L.* and, therefore, the rate of production of hydrogen peroxide, decreased the degree of inactivation.

Treatment of the heart-muscle preparation with *B.A.L.* under conditions which led to complete inactivation of the succinic oxidase system had very little effect (about 10 per cent inhibition) on the cytochrome oxidase activity (measured by the rate of oxidation of ascorbic acid, hydroquinone or *p*-phenylene diamine in the presence of excess cytochrome *c*). The ability of the heart-muscle preparation to catalyse the oxidation of *p*-phenylene diamine in the absence of added cytochrome *c* [7] was inhibited by about 35 per cent by the same treatment.

This treatment with *B.A.L.* did not affect the intensities of the cytochrome $a + a_3$, *b* and *c* bands, after reduction with sodium hydrosulphite, showing that the amounts of these cytochromes were not altered. When, however, succinate was added instead of sodium hydrosulphite, an impairment of the rate of oxidation of cytochrome *b* by cytochrome *c* was observed: thus on adding succinate to heart-muscle preparation treated with *B.A.L.* and shaking with air, the *b*-band alone was visible, that is, in the reduced state (cf. the action of narcotics[1]). The cytochrome *b* could, however, be oxidized by the addition of methylene blue or dichlorphenol indophenol. Although cytochromes $a + a_3$, *b*, *c*, were not destroyed by *B.A.L.*, the total hæmatin content (measured by the intensity of the pyridine-hæmochromogen band at 548–560 mμ after the addition of sodium hydrosulphite and pyridine) was reduced by about 20 per cent when the succinic oxidase system was completely inactivated. Thus treatment with *B.A.L.* destroyed some hæmatin compound the spectrum of which is not visible in the heart muscle preparation, either before or after treatment with hydrosulphite. There was a close correlation between the amount of hæmatin compound destroyed and the



THE COMPONENTS OF THE SUCCINIC OXIDASE SYSTEM

degree of inactivation of the succinic oxidase system when different concentrations of *B.A.L.* were allowed to act on the enzyme for various times.

The enzyme preparation after treatment with *B.A.L.* could not be reactivated by catalase, cytochrome *c*, serum proteins, denatured globin, calcium phosphate gel, Straub's '*SC* factor'[5], copper, aqueous extract of fresh heart-muscle mince (rich in myoglobin) or various fractions of the heart muscle preparation. The enzyme could, however, be protected from the action of *B.A.L.* by the presence, during treatment, of cytochrome *c*, which caused rapid oxidation (through the cytochrome oxidase system) of the dithiol.

Treatment with *B.A.L.* under conditions which caused complete inactivation of the succinic oxidase system, with about 10 per cent inhibition of succinic dehydrogenase, inhibited the activity of the system, measured anaerobically by the rate of reduction of ferricyanide, by 35 per cent.

These observations suggest the existence of a *B.A.L.*-labile factor, probably a hæmatin compound, which transfers electrons from cytochrome *b* to cytochrome *c* and is destroyed by coupled oxidation with reducing agents (cf. the action of ascorbic acid on hæmoglobin, Lemberg *et al.*[8]) when the heart-muscle preparation is treated with reducing agents in the presence of air.

The relationships between this factor and the cytochromes are shown in the accompanying scheme, the arrows showing direction of electron transfer. Thus destruction of the factor would not affect the oxidation of succinate through methylene blue as carrier, nor the oxidation of various reducing agents through cytochromes *c* and *a* and cytochrome oxidase; but would prevent completely the transfer of electrons from cytochrome *b* to cytochrome *c* and thence to molecular oxygen. It is postulated that potassium ferricyanide, with an oxidation-reduction potential (E'_0 at *p*H $7{\cdot}3 = +0{\cdot}41$ V.) much higher than that of succinate ⇌ fumarate (E'_0 at *p*H $7{\cdot}3 = -0{\cdot}01$ V.) or of cytochrome *b* (E'_0 at *p*H $7{\cdot}3 = -0{\cdot}04$ V.) operates partly directly with cytochrome *b* and partly through the *B.A.L.*-labile factor or the cytochromes of higher oxidation-reduction potential (E'_0 of cytochrome $c = +0{\cdot}26$ V., cytochrome $a = +0{\cdot}29$ V.). Thus the destruction of the factor causes a partial, but not complete, inhibition of the rate of oxidation by ferricyanide.

It is possible that the factor is the same as, or closely related to, the component *X* suggested by Bach *et* al.[10] to be necessary for the reduction of cytochrome *c* by cytochrome b_3 in yeast.

The complete experimental data and a discussion of these findings in relation to previous work on the succinic oxidase system will appear elsewhere.

I would like to express my sincere thanks to Prof. D. Keilin for his most valuable advice throughout this investigation. I also wish to thank the British Council for a scholarship.

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PLANT ANALYSIS AND FERTILIZER REQUIREMENTS

A QUICK and reliable method of determining the fertilizer requirements of crops and of discovering what nutrient deficiency is responsible for the unsatisfactory growth of some particular crop would be of immense value in advisory work. The problem can be approached from several different points of view, such as soil analysis, field trials, pot cultures, leaf injection, plant analysis and the use of visual symptoms. The relative advantages and disadvantages of these various methods of diagnosing fertilizer requirements are briefly but clearly summarized in the paper under notice*, and an extensive list of references facilitates fuller study of the individual methods.

A short historical account of the early work on diagnostic plant analysis reminds the reader that there is much to be learnt from these early papers. Developments during the past twenty-five years are discussed in more detail, and a great deal of information on the content of nutrients in plant material in relation to the incidence of deficiency or toxicity symptoms is summarized in tabular form.

Reference is also made to the use of plant analysis in the determination of current nutrient requirements by so-called 'tissue tests'. Carried out on sap or extracts of fresh material, it is suggested that the fractions estimated by these tissue tests are mainly unassimilated material which has recently entered the plant and that their concentration thus represents the *current* rate of nutrient intake. The rapidity with which 'tissue tests' can be performed and the fact that their results can be translated into immediate fertilizer treatment quickly enough to be effective even on annual crops, provided the problem is recognized early in the life of the crop, makes them specially attractive in advisory work. If they can be shown to be reasonably reliable and their interpretation does not require the establishment of a very elaborate series of standards, they seem likely to displace some of the older methods used in advisory work.

As the authors of this paper point out, when defining the aim of a method of deficiency diagnosis, there is an important distinction between methods to be used to improve the nutrition, during the course of its growth, of the crop analysed, and those where the plants analysed serve only as an index of the state of the soil and as a guide to the best fertilizer treatment for subsequent crops.

In a discussion of the relation of internal nutrient concentration to nutrient supply, evidence from barley grown in sand cultures, to which nutrients were added before germination, is used to show that: (1) the concentration in the tissues will depend upon the time during development at which determinations are made; and (2) the results will depend upon the part of the plant chosen for analysis. Analysis of the plant soon after germination (when the seed reserves are exhausted) will give some measure of the concentration of the nutrients in the rooting medium, especially in plants like cereals that branch very rapidly in the early stages.

The bearing of these facts on the relations to be expected with plants growing in the field are complicated by the difference in the mode of supply of the nutrient; for not only are the differences in the

* Chemical Composition of Plants as an Index of their Nutritional Status. (Tech. Comm. No. 17, Imperial Bureau of Horticulture and Plantation Crops.) By Dr. D. W. Goodall and Dr. F. G. Gregory. Pp. 167. (Aberystwyth: Imp. Bur., 1947.) 9s.

concentration of the nutrient in the field of a different order from those in the sand cultures described, but also rates at which nutrients in the soil become available are likely to be more important than actual concentrations in the soil solution, and the supply may continue at a relatively high level throughout the growing period. This is specially important in those types of plant, such as barley, in which nutrients taken up after the stage when further elaboration of meristems ceases lead to no further increase in yield but merely raise the concentration within the plant, thereby checking the normal tendency to decline to a minimum at harvest. Hence plant analyses from field crops can show considerable variations in concentration at harvest. High concentration of nutrient in the mature cereal plant may be due either to limitation of growth by some other nutrient factor leading to 'luxury consumption' or to a high supplying power of the soil maintained throughout the growing period. In the former case, the authors point out that yield will tend to be low and could be improved by the addition of the nutrient in minimum; but in the latter case yield will be high. Hence the use of analyses of mature cereal plants as indicators of the nutritional status of soils depends on the fact that differences in the nutrient-supplying power of the soil persist throughout the growing season, leading to accumulation at harvest, and not upon any causal relationship between final internal nutrient concentration and yield.

A good deal of consideration is given to the best method of selecting plants for analysis, to the influence of time of day and time of year or stage of development of the plant when samples are taken, and to the advantages of analysing the whole plant as compared with a single organ of the plant. On the subject of which organ is likely to prove the most suitable for analysis, the authors have collected all the available evidence and present it in tabular form under the various crops. In the majority of cases the leaves seem to show the greatest proportional increase in internal concentration of a nutrient with increase in its supply. Necessary precautions in the preparation of material for analysis are discussed, followed by consideration of the analysis itself, including the need to determine particular chemical fractions and the choice of extraction methods.

The interpretation of the results of diagnostic analysis is perhaps the most difficult part of the whole problem of the use of plant analysis to determine fertilizer needs. Standards of reference are essential, together with data on the performance of the plants from which they are derived. To establish standard values for internal nutrient content requires data on the yield responses of plants at varying levels of nutrition and on their composition. Emphasis is placed on the dangers of basing conclusions on data for a single element without allowing for variations in the content of other nutrients. Nevertheless, it is pointed out that many investigators have specified optimal levels or limiting values above which the supply of a particular nutrient may be regarded as adequate, presumably where the content of other nutrients is not limiting. A comprehensive table of these suggested standard values for nutrient content of a wide variety of crops is included in the paper.

Suggestions by numerous workers for standard ratios of various plant nutrients are also given in tabular form; but the authors state that in their opinion there is no reason for supposing that ratios of nutrients in general are likely to be of greater use in diagnostic work than the content of the elements individually. They consider that ratios of nutrients within the plant should generally be used in conjunction with data for individual concentrations. The authors express the view that 'foliar diagnosis' work must be subject to much the same criticisms as other work involving the use of ratios.

In their final consideration of the place of plant analysis among other methods of nutritional diagnosis, the authors suggest that a combination of soil and plant analyses may give the most satisfactory results: soil analysis to determine pre-planting fertilizer treatment, and plant analysis for perennial crops and to indicate the need of annual crops for side or top dressings of fertilizer. Diagnosis by visual symptoms is an easy and rapid method where symptoms can be readily and definitely recognized, but has the disadvantage that waiting for deficiency symptoms to appear before treatment can be given may reduce the final yield.

SOCIOLOGY OF MENTAL DISEASE

THE physical and biological sciences have at last been accepted as indispensable adjuncts to the art of government, but the psychological and sociological lag behind. No clearer evidence of this is needed than the assumption that the men of science whose help should be asked to solve the problem of controlling atomic bombs are those who are specialists in making the machine rather than those who are specialists in the study of the minds likely to set the machine in motion.

It is encouraging, therefore, that the National Association for Mental Health should have had full and practical governmental support for its conference in the Seymour Hall during January 15–16. By sanctioning the payment of expenses, the various Ministries secured a very large attendance of delegates from local authorities. Moreover, the Parliamentary Secretary to the Minister of Health contributed that rarest of things—an opening address which must have usefully coloured the minds of everybody throughout the ensuing meetings.

Mr. Edwards emphasized that mental illness is a social disease with sequelæ deleterious to national and international life, that its consequences affect production drives, foreign policies, the family institution, and the efficacy of education. Moreover, it is a matter which cannot be left simply to technicians, since it affects every individual, however sane potentially, since complete sanity is impossible for anyone who has to live in a community riddled with mental and nervous troubles.

Dr. G. R. Hargreaves, principal medical officer of Lever Bros. and Unilever, Ltd., and Dr. Donald Stewart, medical adviser to the Austin Motor Co., provided the text for the conference by epitomizing the Russell Fraser Report on the incidence of neurosis among factory workers*. In a sample of more than three thousand male and female workers in light and medium engineering factories, 10 per cent suffered from definite and disabling neurotic illness and a further 20 per cent from minor forms of neurosis during the course of six months. Neurotic illness accounted for a loss of three working days by every man studied and six days by every woman. It is at least as important a source of industrial loss as colds and influenza, or accidents and industrial disease.

* No. 90. Industrial Health Research Board, 1947. (H.M. Stationery Office.) 1s. 3d.

Moreover, since neurosis is a disease of human relationships, in which the sick man's associates and family suffer, there must be added an incalculable loss caused by interference with the smooth working of those who do not themselves report sick.

Dr. Hargreaves suggested that hitherto social effort has been concentrated on psychotics and serious certifiable disease too exclusively, and that so long as the whole problem outruns the supply of trained personnel it is wiser to concentrate on the lighter neurotic diseases which interfere far more with the social machine than the psychotic do.

Dr. Kenneth Soddy, medical director of the National Association for Mental Health, and Dr. Doris M. Odlum, vice-president, discussed the obligations and opportunities given to local authorities by the National Health Service Act, 1946, in dealing with this problem.

Dr. Soddy gave a series of case-histories which showed that the problem of the neurotic cannot be treated as a purely medical one, and that the psychiatric social worker has a specific task, involving the mastering of a difficult technique, to co-ordinate the various administrative organs which might be needed to cope with a socially and personally 'unstuck' individual.

It is clear that the provision of sufficient trained psychiatric social workers—one in 2,500 of the population—is virtually impossible for many years. Not only is it impossible to train this number; but also there are probably not sufficient people of the right character and temperament fit for training. It is on this problem that it was possible to sense a difference of opinion within the conference.

On one hand, Dr. Greenwood Wilson, medical officer of health at Cardiff, speaking as a delegate, said that Cardiff proposes to use health visitors to help supplement the trained psychiatric workers, and pointed out that health visitors are not only experienced in human nature, but also masters of the special technique of breaking into the family circle in quest of private and intimate information. On the other hand, Brigadier A. Torrie, director of army psychiatry, gave his opinion that only a person with psychiatric training could be entrusted with any part of the work. It is to be hoped that Brigadier Torrie is wrong, since we shall not have a hundredth part of the required army of psychiatric workers trained for years to come. Fortunately, the National Association for Mental Health is aware of the danger of establishing a vested interest point of view on this matter.

The real difficulty is that applied psychiatry involves two requisites: a technique to be acquired by a specific training, and a personal character which cannot as yet be acquired. An industrial physicist or chemist may be a drunkard, a wife-beater or a child murderer without it necessarily interfering with his scientific work; but an industrial psychiatrist can ill afford these idiosyncrasies.

Whatever it means to-day, psychology used to mean the study of the human 'soul', and there used to be a profession or a vocation called a 'cure of souls'. Why the cure of souls has been taken over from the clergyman by the psychiatrist is a question which cannot be gone into here. Possibly there are too many clergy who have character without technique, but it is certain that technique by itself will be no adequate substitute for character. The admirable speech of the Earl of Feversham, chairman of the National Association, left the conference in no doubt that the Association is fully alive to this necessity for wedding technique and character in all cure of souls, and along with Mr. Edwards' opening address must have sent the delegates away realizing that they must act not only as administrators but also as human beings if the rising tide of mental sickness is to be held back. Both Dr. Odlum and Miss Clare Britton repeatedly emphasized that good results depended on personnel who know how to be humane. Miss Britton made a good point when she suggested that personnel for boarding schools for difficult children should never be expected to spend more than seven years of their lives at this exacting task. All psychiatry involves such inroads on emotional resources, apart altogether from its demands on those parts of the human intellect usually called upon for scientific work, that it should only be practised for limited periods.

It is to be hoped that all local authorities represented at the conference will have been impressed with the opportunities afforded them under the new Act for dealing with the chronic minor diseases of human relationships which cause so much more trouble than the far rarer and more spectacular mental disorders to which their attention was once confined.

ASSOCIATION OF BRITISH ZOOLOGISTS

DESPITE the predominantly urban nature of the population of Great Britain, one of its characteristics at the present time is a reawakened interest in, and a feeling of responsibility for, the countryside. This is made more acute by the realization of the part which agricultural workers can play in supplying food, and by the fear that, in a small island like Great Britain, indiscriminate exploitation by industry or the Services might destroy what could never be replaced. That this spirit is beginning to permeate the teaching of biological subjects in both schools and universities was indicated at the meeting of the Association of British Zoologists held on January 8, in the rooms of the Zoological Society of London. Prof. H. Graham Cannon was in the chair and the general topic of discussion was "The Field Study and Conservation of the British Fauna".

The universities of Britain are, for the most part, situated in its big towns, and at present the combined difficulties of congested time-tables, large classes and inadequate staff often mean that little or no field-work can be introduced into their zoological courses. Such work of this type as has been done in the past has almost invariably been marine, and the field courses of longest standing are those held at the various marine laboratories. These, as was stressed by Prof. F. W. Rogers Brambell, must remain the most important in the training of the general zoologist; but they should be supplemented by others which would introduce the student to freshwater or entomological ecological problems, and which would provide special training in these where that is necessary. Prof. J. W. Munro described in this connexion the way in which the Silwood Park Field Station of the Imperial College of Science and Technology could be used for both undergraduate teaching and for introducing post-graduate workers to field research in entomology—a very important development if many of the schemes for the Colonies, such as that for growing groundnuts in Africa, are to be supplied with properly trained biologists. Without the help of such men, all these

projects were liable to failure, with very grave consequences for both the Colonies and for Britain.

Mr. F. H. C. Butler, director of the Council for the Promotion of Field Studies, explained how this five-year-old body functions, and described how the centres which the Council operates at Flatford Mill, Juniper Hall, Malham Tarn, and Dale Fort might be used to increase the variety of types of field work now possible. These offered to school-children, university students and private individuals alike the opportunity of doing supervised work in the field on biological and related subjects, of observing the interaction of these studies and so counteracting the tendency towards over-specialization. Dr. E. A. Ennion, warden of the Council's centre at Flatford Mill, gave an account of the way in which work there is carried out, stressing in particular the precautions which are taken to ensure that the natural life of the environment is conserved and that rare species are not rendered extinct by over-zealous collecting.

This particular example of a more general danger led the Association to consider the topic of the conservation of the wild life of England and Wales, Capt. C. Diver describing the proposals of the Wild Life Conservation Special Committee. These include the setting aside of certain parts of Britain as Nature reserves and the starting of a State biological advisory service. A specific instance of the way in which properly trained biologists could act to ensure efficient public services and economy of public money was given by Prof. E. A. Spaul, of the University of Leeds, who described some of the work done by zoologists there on the biology of sewage and sewage disposal, much of which has been shown to depend upon the animal population of the filters. Mr. R. S. R. Fitter gave some examples of the type of problem—bird migrations, liberation of populations of known genetic constitution—to which answers might be found by the use of the special category of experimental Nature reserves which are also proposed.

NATURAL SELECTION OF *DROSOPHILA*

RECENT studies on wild populations of *Drosophila* are shedding considerable light on the effects of natural selection. By means of the cytological examination of salivary gland chromosomes, it is possible to analyse the nuclear constitution more precisely than in other living forms. For example, an inversion of part of a chromosome *abcde* to form a different chromosome *adcbe* is not infrequent, and may be quickly detected in the hybrid between two *Drosophila* containing these respective chromosomes. Generally there is no apparent difference in the characters of the individuals carrying normal or inverted chromosome arrangements. Occasionally, however, a large position effect is noted such as in 'roughoid' (Gruneberg, 1939).

Dobzhansky[1] and Dubinin and Tiniakov[2] have shown that the proportion of individuals carrying an inversion alters with time and place in wild populations of *D. funebris* and in *D. pseudoobscura*. For example, Dubinin and Tiniakov show that the proportions of individuals of *D. funebris* with inversions is lower in urban than in rural districts, and that under the intense natural selection of winter conditions the inversions III, II2 and II4 were greatly reduced in proportion, whereas the inversion IV1 increased slightly. On the other hand, these inversions increased rapidly in proportion during the summer up to a maximum when the population was at its prime.

Similarly, Dobzhansky has shown that cyclic changes with the seasons took place in a wild population of *D. pseudoobscura* at Pinon Flats, California. These changes were on the whole constant during the years 1939–46. There was no trend towards one particular chromosome arrangement, although the proportions in the population were significantly different at different times of each year. This evidence becomes more significant when it is found that the same chromosome arrangements do show a definite trend at Keens Colony, which is 15 miles from Pinon Flats. During the years 1939–46 the standard arrangement increased in the population from 30 to 50 per cent, whereas the 'Arrowhead' arrangement decreased from 30 to 15 per cent. In all these cases no detectable difference in the morphology or physiology of the animals with different chromosomes has been observed.

In *D. pseudoobscura* the inversion heterozygotes are adaptively favoured in comparison with both the homozygotes; but in *D. funebris* there appears to be no difference between the inversion homozygote and the inversion heterozygote in respect of survival value. In each of the above cases either one simple or one compound rearrangement is present on one chromosome; it is expected and found that there is a consequent instability and increased plasticity of the population.

Recently a constant breeding population of *D. funebris* consisting entirely of individuals heterozygous for three inversions on chromosome 5 has been found near Manchester by Berrie and Sansome[3]. The three inversions are evenly placed on the chromosome, and no homozygotes have as yet been obtained among the forty individuals caught, or in their progeny. A multiple, probably successive, series of chromosome arrangements had occurred and a highly stable heterozygous system was the result. Obviously, the creation of such a system must be fortuitous, at least in respect of the occurrence of the inversions; but natural selection could control the trend of the subsequent evolution.

F. W. SANSOME

[1] Dobzhansky, Th., *Heredity*, **1**, 56 (1947).
[2] Dubinin, N. P., and Tiniakov, G. S., *Amer. Nat.*, **79**, 785 (1945); *C.R. Acad. Sci., U.S.S.R.*, **51**, 155 (1946); *J. Gen.*, **48**, 11 (1947).
[3] Berrie, G. K., and Sansome, F. W. (in the press).

ORIBATID MITES AND THEIR ECONOMIC IMPORTANCE

By M. ANANTARAMAN
Madras Veterinary College

REVIEWING some of the literature on Tyroglyphid mites, Lapage[1] directed attention to their role in pulmonary acariasis of man, in addition to destruction of stored food-products. The Oribatids are allied to these cheese- and flour-mites and to the well-known harvest- and chigger-mites, and have been, until a few years ago, of comparatively little economic significance. Otherwise known as moss-mites and beetle-mites, they have been studied for many years and from all over the world. They are mostly microscopic in size, free-living and terrestrial, although a few are aquatic and crawl on weeds. Their activity is greater in darkness, when they swarm out in search of food, and progression is

normally slow. They have a shiny chitinous body-wall, a wing-like extension (the pteromorpha) at the antero-lateral corner of the abdomen on each side, a pair of peculiarly shaped sense-organs (the pseudostigmatic organs), and no eyes.

By and large denizens of the soil, the oribatid mites occur in decaying vegetation, among fungal mycelia, moss or algæ, and form a conspicuous group amid the soil biota. Some are confined to the soil and migrate on blades of grass during the night; others conceal themselves in the bark of trees or crawl on twigs and leaves. Depending upon their habitat, they are classified as terricolous, dendricolous, bryobious and humicolous.

In the group Acarina, which comprises parasites (Ixodoidea and Sarcoptidæ), predators (Trombidiidæ), and suckers of plant sap (Tetranychidæ), the Oribatoidea are outstanding in being herbivorous or saprophagous. They feed on moulds (fungivorous), algæ, decaying leaves or animal matter, and are distinctly inoffensive. Consequently, although systematists like Banks, Berlese, Nicolet, Michael, Oudemans, Jacot, Grandjean and Ewing have revealed the abundant and ubiquitous occurrence of these organisms, very few investigators attributed any importance to them. Michael[2], in his monograph, has remarked that none of the species is "injurious to man or his works". Jacot[3] regarded them as "negative, humble and devoid of weapons of offense"; afterwards[4], he commented on the occurrence of *Damæosoma alces*, *Protoschelobates pembertoni* and *Xylobates pembertoni* in holes in cane roots, of *Lohmannia insignis* on bean seedlings and of *L. insignis dissimilis* on tulip bulbs as having no significance, because no evidence could be adduced that the holes were caused by the mites. He concluded that "the case against oribatides as non-injurious is becoming weightier".

Stunkard's[5] experiments on the development of *Moniezia expansa* disclosed the identity of the intermediate host of this tapeworm. He announced that *Zetes* (*Galumna*) *emarginatus* harboured the cysticercoids of the worm to the infective stage, and this discovery heralded a series of publications on the life-cycles of other Anoplocephalid cestodes. The work of Krull[6] (U.S.A.) on *Cittotænia* and *Moniezia*, of Stunkard[7] (U.S.A.) on *Bertiella studeri*, of Pullar[8] (Australia) on *Moniezia*, of Baahkirova[9] (U.S.S.R.) on *Anoplocephala* spp., and *Paranoplocephala mamillana*, of Potemkina[10] (U.S.S.R.) on *Thysaniezia ovilla*, and of the present writer[11] (India) on *Moniezia expansa* and *M. benedeni*, has involved oribatid mites of various genera and species as the undoubted vectors of these worms. Moreover, the same species of mite is observed to be capable of conveying more than one species of the cestode in a locality.

The Anoplocephalid tapeworms, characteristically devoid of rostellar hooks, are among the worst enemies of livestock, and to the veterinary parasitologist the oribatid mite has therefore suddenly become of major importance.

[1] *Nature*, **156**, 427 (1945).
[2] "British Oribatoidea", **1** (1884).
[3] *Amer. Nat.*, **59**, 272 (1925).
[4] Bern. P. Bishop Mus. Bull., **121**, 93 (1934).
[5] *Parasit.*, **30**, 491 (1938).
[6] *Proc. Helm. Soc. Wash.*, **6**, (1), 10 (1939).
[7] *Amer. J. Trop. Med.*, **20** (2), 305 (1940).
[8] *Austral. Vet. J.*, **15**, (2), 71 (1939).
[9] *C.R. Acad. Sci. URSS.*, (N.S.) **30**, (6), 576 (1941) (in English). *Vestn. Sel.-khoz. Nauk., Veterinariya*, No. 2, 57 (1941, in Russian, with French summary).
[10] *C.R. Acad. Sci. URSS.*, (N.S.), **30**, (5), 474 (1941); **43**, (1), 43 (1944).
[11] Unpublished work.

THE MESON FIELD AND THE EQUATION OF MOTION OF A SPINNING PARTICLE

By R. C. MAJUMDAR and Dr. S. GUPTA
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THE outstanding difficulty in obtaining the equation of motion of a spinning particle in a meson field which will take account of the reaction of the emitted meson field and is free from singularities is well known. The equation of motion was first obtained by Heisenberg[1] for a dipole of finite extension and is therefore not relativistically invariant. The relativistically invariant equations of motion for a point dipole which have been developed by Bhabha and Corben[2] and by Bhabha[3] are extremely complicated and involve a number of arbitrary constants which are not determined uniquely. These equations in their final form are free from singularities, and have been proved to involve only the contribution of the so-called radiation field, defined as half the retarded minus the advanced field, which is finite on the world line. However, the equations are established by proving that the singular terms are perfect differentials and can therefore be subtracted away.

In 1939, Riesz[4] developed an elegant method for solving the differential equations of hyperbolic type in which the divergent difficulties are avoided by a process of analytical continuation. The method has been recently applied by Fremberg[5] to obtain the classical equation of motion of a charged particle in an electromagnetic as well as in a meson field. Following Riesz, we shall define the potential and the field of a dipole for a parameter $\alpha > 2$ and show that the analytical continuation to $\alpha = 2$ gives the classical values corresponding to those of Lienard-Wiechert outside the world line, and a finite value on the world line itself giving the reaction of the field. The equations of motion of a point dipole can then be obtained in a straightforward way from the usual equation of a dipole as given by Frenkel[6]. The equations are free from singularities and do not contain any arbitrary constant except the spin angular momentum of the dipole.

We define the Riesz potential for the dipole at a point $P(\mathbf{x})$ outside the world line in the form,

$$\varphi_\nu^{\alpha}(P) = \frac{g_2 \chi^{4-\alpha}}{2^{\frac{1}{2}(\alpha-2)} \sqrt{(\alpha, 2)}} \frac{\partial}{\partial x_\mu} \int_{-\infty}^{\tau_0} S_{\mu\lambda}(\tau)\, (\chi s)^{\frac{1}{2}(\alpha-4)}\, J_{\frac{1}{2}(\alpha-4)}(\chi s) d\tau, \quad (1)$$

where τ is the proper time of the particle, τ_0 the retarded point of P, $J_n(x)$ is the Bessel function of order n and $g_2 S_{\mu\nu}$ is the antisymmetrical tensor describing the dipole moment. The four-dimensional distance s is given by

$$s^2 = s_\mu s^\mu, \quad s_\mu = x_\mu - z_\mu. \quad (2)$$

The integral converges for $2 < \alpha < 5$. The potential (1) satisfies the wave equation of a dipole in a meson field given by

$$\frac{\partial}{\partial x_\rho} \frac{\partial}{\partial x^\rho} \varphi_\mu + \chi^2 \varphi_\mu = 4\pi \frac{\partial}{\partial x_\nu} S_{\nu\mu}, \quad . \quad (3)$$

when we continue analytically to $\alpha = 2$.

Now it can be shown after some calculations that the analytical continuation to $\alpha = 2$ of the Riesz potential (1) and the corresponding field-strength for

the dipole lead to the well-known Lienard - Wiechert results, as already obtained by Bhabha and Corben :

$$\varphi_\nu^2(P) = \varphi_\nu^{\text{ret}} = g_2\left[\frac{1}{\varkappa}\frac{d}{d\tau}\left(\frac{s^\mu S_{\mu\nu}}{\varkappa}\right)\right]_0 - \frac{g_2\chi^2}{2}\left[\frac{s^\mu S_{\mu\nu}}{\varkappa}\right]_0 + g_2\chi^2\int_{-\infty}^{\tau_0}\frac{s^\mu S_{\mu\nu}}{s^2}\,J_2(\chi s)d\tau, \quad (4)$$

$$F_{\mu\nu}^2(P) = F_{\mu\nu}^{\text{ret}} = g_2\left[\frac{1}{\varkappa}\frac{d}{d\tau}\left(\frac{S_{\mu\nu}}{\varkappa}\right)\right]_0 + g_2\left[\frac{1}{\varkappa}\frac{d}{d\tau}\left(\frac{1}{\varkappa}\frac{d}{d\tau}\left(\frac{T_{\mu\nu}}{\varkappa}\right)\right)\right]_0 - \frac{g_2\chi^2}{2}\left[\frac{S_{\mu\nu}}{\varkappa}\right]_0 - \frac{g_2\chi^2}{2}\left[\frac{1}{\varkappa}\frac{dT_{\mu\nu}}{d\tau}\right]_0 + \frac{g_2\chi^4}{8}\left[\frac{T_{\mu\nu}}{\varkappa}\right]_0 + g_2\chi^2\int_{-\infty}^{\tau_0}\frac{S_{\mu\nu}J_2(\chi s)}{s^2}d\tau - g_2\chi^3\int_{-\infty}^{\tau_0}\frac{T_{\mu\nu}J_2(\chi s)}{s^2}d\tau - \text{the same terms with } \mu \text{ and } \nu \text{ interchanged}, \quad (5)$$

where $\varkappa = s_\mu v^\mu$, $T_{\mu\nu} = s_\mu s^\sigma S_{\sigma\nu}$. The suffix 0 implies that the value of the function is to be taken at the retarded point of P.

In order to calculate the potentials and the fields at a point P on the world line, we divide the integrals into two parts, one in the interval $-\infty$ to $\tau_0 - \varepsilon$, and the other from $\tau_0 - \varepsilon$ to τ_0. It is easily seen that the first integral vanishes for $\alpha = 2$. We then expand the quantities in the second integral in power series of τ, measured from τ_0 taken as zero, and obtain by analytical continuation to $\alpha = 2$ the following expressions :

$$\varphi_\nu^{\alpha=2} \text{ (on the world line)} = -g_1\left[\frac{1}{3}\ddot{v}\mu S_{\mu\nu} - \frac{1}{3}v^\mu S_{\mu\nu}(v\ddot{v}) + \dot{v}^\mu\dot{S}_{\mu\nu} + v^\mu\ddot{S}_{\mu\nu}\right] - \frac{1}{2}g_2\chi^2 v^\mu S_{\mu\nu} + g_2\chi^2\int_{-\infty}^{\tau_0} s^\mu S_{\mu\nu}\frac{J_2(\chi s)}{s^2}d\tau, \quad (6)$$

$$F_{\mu\nu}^{\alpha=2} \text{ (on the world line)} = g_1\left[\frac{2}{3}S_{\mu\nu}(\dddot{v}\ddot{v}) + \frac{2}{3}\dot{S}_{\mu\nu}\dot{v}^2 + \frac{2}{3}\dddot{S}_{\mu\nu} - \left\{\frac{4}{3}v_\mu S_\nu''' + 2\dot{v}_\mu S_\nu'\dot{v}^2 + \frac{1}{3}\ddot{v}_\mu \$_\nu + \frac{2}{3}\ddot{v}_\mu\dot{v}^\sigma S_{\sigma\nu} + \frac{4}{3}\ddot{v}_\mu S_\nu' + \frac{4}{3}v_\mu\ddot{v}^\sigma\dot{S}_{\sigma\nu} + \frac{2}{3}\dot{v}_\mu\dot{v}^\sigma S_{\sigma\nu} + \frac{1}{3}v_\mu\dddot{v}^\sigma S_{\sigma\nu} + 2v_\mu\dot{v}^\sigma\ddot{S}_{\sigma\nu} + 2\dot{v}_\mu S_\nu'' + 2\ddot{v}_\mu\dot{v}^\sigma\dot{S}_{\sigma\nu} + 2v_\mu\$_\nu(\dot{v}\ddot{v}) + v_\mu\dot{v}^\sigma S_{\sigma\nu}\dot{v}^2 + \dot{v}_\mu\$_\nu\dot{v}^2\right\}_- + \chi^2\left\{\dot{S}_{\mu\nu} - [v_\mu S_\nu']_- - \frac{1}{2}[v_\mu\dot{v}^\sigma S_{\sigma\nu}]_- - \frac{1}{2}[\dot{v}_\mu\$_\nu]_-\right\}\right] + 2g_2\chi^2\int_{-\infty}^{\tau_0} S_{\mu\nu}\frac{J_2(\chi s)}{s^2}\,d\tau - g_2\chi^3\int_{-\infty}^{\tau_0}[s_\mu s^\sigma S_{\sigma\nu}]_-\frac{J_2(\chi s)}{s^2}\,d\tau, \quad (7)$$

where

$$\$_\nu = v^\sigma S_{\sigma\nu},\ S_\nu' = v^\sigma\dot{S}_{\sigma\nu},\ S_\nu'' = v^\sigma\ddot{S}_{\sigma\nu},\ S_\nu''' = v^\sigma\dddot{S}_{\sigma\nu}, \quad (8)$$

and the minus sign as subscript denotes that the terms inside the brackets are to be subtracted with interchange of μ and ν.

It is to be noticed that the field given by (7) is, in fact, the retarded field, and agrees with the so-called radiation field of Dirac as obtained by Bhabha and Corben, provided we put $k_1 = -1/3$, $k_2 = -7/15$, $k_3 = 1/3$, $k_4 = 4/3$, $k_5 = 0$ in (140) (Bhabha and Corben) and $k = 2$ in (110) (Bhabha). There is, however, disagreement in terms with constant k_3, which has also been noticed by Harish-Chandra[7], whose calculations of the radiation field on the world line by retaining the finite and the unambiguous terms of the fields agrees with our result (7).

The equation of motion is now obtained from Frenkel's equation

$$I\,\dot{S}_{\mu\nu} = g_2[S.F^{\text{ext}}]_{\mu\nu} + g_2[S.F^{\text{react}}]_{\mu\nu}, \quad (9)$$

where I is the spin angular momentum. The field $F_{\mu\nu}$ in the second term of the right-hand side is given by (7) above. The equation of motion of a point dipole in a scalar meson field is also similarly obtained.

The detailed paper will be published in due course in the *Physical Review*.

[1] Heisenberg, W., *Z. Phys.*, **113**, 61 (1939).
[2] Bhabha, H. J., and Corben, H. C., *Proc. Roy. Soc.*, A, **178**, 273 (1941).
[3] Bhabha, H. J., *Proc. Roy. Soc.*, A, **178**, 314 (1941).
[4] Riesz, M., Conférence de la Réunion internat. des math. tenue à Paris en Juillet 1937 (Paris, 1939). Prof. Riesz's papers are unfortunately not available in India.
[5] Fremberg, N. E., *Medd. Lunds Univ. Mat. Sem.*, **7** (1946) *Proc. Roy. Soc.*, A, **188**, 18 (1946).
[6] Frenkel, J., *Z. Phys.*, **37**, 243 (1926).
[7] Harish-Chandra, *Proc. Roy. Soc.*, A. **185**. 269 (1946).

FORTHCOMING EVENTS

*(Meetings marked with an asterisk * are open to the public)*

Monday, March 15

ROYAL PHYSICAL SOCIETY OF EDINBURGH (at the Royal Scottish Geographical Society, Synod Hall, Castle Terrace, Edinburgh), at 5.15 p.m.—Prof. T. N. George : "Fossils and Evolutionary Theory".

MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY (in the Reynolds Hall, College of Technology, Manchester), at 5.30 p.m.—Sir Charles Goodeve, F.R.S. : "Operational Research".*

UNIVERSITY COLLEGE (in the Anatomy Theatre, Gower Street, London, W.C.1), at 5.30 p.m.—Dr. George Sarton : "Science and Tradition". (Further Lectures on March 16 and 19.)*

ROYAL INSTITUTE OF CHEMISTRY, LONDON AND SOUTH-EASTERN COUNTIES SECTION (joint meeting with the DARTFORD BRANCH of the PHARMACEUTICAL SOCIETY, at the County Technical College, Essex Road, Dartford), at 7.15 p.m.—Dr. A. Albert : "Physico-Chemical Concepts in Interpreting Drug Action".

Tuesday, March 16

BRITISH PSYCHOLOGICAL SOCIETY, INDUSTRIAL SECTION (at the London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1), at 1 p.m.—Annual General Meeting ; Mr. Dermot Straker : "The Importance of Information in Vocational Selection".

CHADWICK PUBLIC LECTURE (in the Sir Edward Meyerstein Lecture Theatre, Westminster Hospital Medical School, 17 Horseferry Road, London, S.W.1), at 2.30 p.m.—Dr. J. R. Nicholls : "Adulteration of Food and its Detection".*

ROYAL SOCIETY OF ARTS, DOMINIONS AND COLONIES SECTION (at John Adam Street, Adelphi, London, W.C.2), at 2.30 p.m.—Dr. E. Marsden, F.R.S. : "Co-ordination of Research in the Pacific".

LINNEAN SOCIETY OF LONDON (joint meeting with the SYSTEMATICS ASSOCIATION, at Burlington House, Piccadilly, London, W.1), at 5 p.m.—Discussion on "The Organization of Taxonomic Research".

ROYAL ANTHROPOLOGICAL INSTITUTE (at 21 Bedford Square, London, W.C.1), at 5 p.m.—Miss Laura E. Start : "Indian Textiles from Guatemala and Southern Mexico".

ROYAL STATISTICAL SOCIETY (at the London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1), at 5.15 p.m.—Mr. F. J. Anscombe : "The Validity of Comparative Experiments".

EUGENICS SOCIETY (at the Royal Society, Burlington House, Piccadilly, London, W.1), at 5.30 p.m.—Dr. W. Mayer Gross : "Mental Health Survey in a Rural Population".*

CONWAY DISCUSSION CIRCLE (at Conway Hall, Red Lion Square, London, W.C.1), at 7 p.m.—Dr. W. E. Swinton : "The Rise and Fall of the Dinosaurs".*

INSTITUTION OF THE RUBBER INDUSTRY (at Caxton Hall, Caxton Street, London, S.W.1).—Dr. D. A. Harper : "The Technology of some New Condensation Rubbers".

Tuesday, March 16—Thursday, March 18

INSTITUTE OF METALS (at the Institution of Civil Engineers, Great George Street, London, S.W.1).—Annual General Meeting.

Wednesday, March 17

SOCIETY OF CHEMICAL INDUSTRY, FOOD GROUP (joint meeting with the MIDLAND SECTION OF THE SOCIETY OF DAIRY TECHNOLOGY, at the Technical College, Wolverhampton), at 2.15 p.m.—Discussion on "The Chemical Sterilization of Food Plant" (to be opened by Dr. E. B. Hughes and Mr. J. C. L. Resuggan).

ROYAL INSTITUTE OF CHEMISTRY, LONDON AND SOUTH-EASTERN COUNTIES SECTION (joint meeting with the LONDON BRANCH of the INSTITUTE OF PHYSICS, at the Royal Institution, Albemarle Street, London, W.1), at 2.30 p.m.—Dr. A. E. Alexander: "Emulsions and Emulsification".

ROYAL SOCIETY OF ARTS (at John Adam Street, Adelphi, London, W.C.2), at 2.30 p.m.—Prof. H. G. Champion: "Re-afforestation as a World Problem".

GEOLOGICAL SOCIETY OF LONDON (at Burlington House, Piccadilly, London, W.1), at 3 p.m.—Annual General Meeting; Prof. H. H. Read, F.R.S.: "Place in Plutonism" (Presidential Address).

ROYAL METEOROLOGICAL SOCIETY (at 49 Cromwell Road, London, S.W.7), at 5 p.m.—Discussion on "Atmospheric Turbulence".

ROYAL MICROSCOPICAL SOCIETY (at B.M.A. House, Tavistock Square, London, W.C.1), at 5.30 p.m.—Dr. R. J. Ludford: "Application of the Barnard Ultra-Violet Light Technique for the Study of Living Cells"; Mr. J. Smiles: "New Development in Visual Light Microscopy".

BRITISH INSTITUTION OF RADIO ENGINEERS, SCOTTISH SECTION (at the Heriot Watt College, Edinburgh), at 6.30 p.m.—Dr. Angus Campbell: "The Development of Radiology".

MANCHESTER METALLURGICAL SOCIETY (at the Engineers' Club, Albert Square, Manchester), at 6.30 p.m.—Annual General Meeting; Mr. R. S. Brown: "Modern Heat Treatment Furnaces".

SOCIETY FOR VISITING SCIENTISTS (at 5 Old Burlington Street, London, W.1), at 7.30 p.m.—Discussion on "The Growing Points in Science", 3. (To be opened by Prof. O.R. Frisch and Dr. K. Weissenberg.)

INSTITUTION OF NAVAL ARCHITECTS (at 10 Upper Belgrave Street, London, S.W.1).—Annual General Meeting.

Wednesday, March 17—Friday, March 19

INSTITUTION OF NAVAL ARCHITECTS (at the Royal United Services Institution, Whitehall, London, S.W.1).—Eighty-ninth Annual Meetings.

Thursday, March 18

CHEMICAL SOCIETY (in the Lecture Theatre, Physical Chemistry Laboratory, South Parks Road, Oxford), at 12 noon.—107th Annual General Meeting; at 3 p.m.—Prof. C. N. Hinshelwood, F.R.S.: "Some Aspects of the Chemistry of Hydrocarbons" (Presidential Address).

ROYAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Mr. J. D. Griffith Davies: "John Wilkins and the Royal Society" (The Wilkins Lecture).

INSTITUTION OF MINING AND METALLURGY (at the Geological Society, Burlington House, Piccadilly, London, W.1), at 5 p.m.—Mr. H. R. Potts: "Further Notes on Converter Practice at Rio Tinto".

LONDON MATHEMATICAL SOCIETY (at the Royal Astronomical Society, Burlington House, Piccadilly, London, W.1), at 5 p.m.—Prof. G. Birkhoff: "Lattice Theory and its Applications".

BRITISH GLACIOLOGICAL SOCIETY (at the Royal Geographical Society, Kensington Gore, London, S.W.7), at 5.15 p.m.—Dr. A. Farrington: "The Glacial Drifts of the Leinster Chain".

ILLUMINATING ENGINEERING SOCIETY, MANCHESTER CENTRE (in the Reynolds Hall, College of Technology, Manchester), at 6 p.m.—Mr. T. S. Jones: "School Lighting".

ROYAL AERONAUTICAL SOCIETY (at the Institution of Civil Engineers, Great George Street, London, S.W.1), at 6 p.m.—Mr. H. Davies: "Flight Testing at High Subsonic Speeds".

OIL AND COLOUR CHEMISTS' ASSOCIATION, LONDON SECTION (at the Royal Society of Tropical Medicine and Hygiene, Manson House, 26 Portland Place, London, W.1), at 7 p.m.—Dr. L. Ivanovsky and Dr. A. C. Healey: "The Uses of Greases and Waxes in Printing Ink and Related Materials".*

ROYAL PHOTOGRAPHIC SOCIETY, SCIENTIFIC AND TECHNICAL GROUP (at 16 Prince's Gate, London, S.W.7), at 7 p.m.—Symposium on "Photography in Nuclear Research".

Friday, March 19

PHYSICAL SOCIETY, COLOUR GROUP (in the Small Physics Lecture Theatre, Imperial College of Science, Imperial Institute Road, London, S.W.7), at 3.45 p.m.—Eighth Annual General Meeting; Mr. J. G. Holmes: "The Aims and Activities of the Colour Group"; at 5 p.m.—Mr. J. G. Holmes: "The Physical Structure of Coloured Glass".

INSTITUTION OF ELECTRICAL ENGINEERS (joint meeting of the MEASUREMENTS and TRANSMISSION SECTIONS, at Savoy Place, Victoria Embankment, London, W.C.2), at 5.30 p.m.—Mr. E. W. Connon and Mr. E. Smith: "The Influence of Inverse Time Relay Characteristics on Discriminative Time".

INSTITUTION OF MECHANICAL ENGINEERS (at Storey's Gate, St. James's Park, London, S.W.1), at 5.30 p.m.—Annual General Meeting.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS (at the Mining Institute, Newcastle-upon-Tyne), at 6.15 p.m.—Mr. Arnold Emerson and Mr. N. A. Witney: "Experiment Work on Merchant Ship Models during the War".

BRITISH INSTITUTION OF RADIO ENGINEERS, MIDLAND SECTION (at the Technical College, The Butts, Coventry), at 6.30 p.m.—Mr. N. E. Head: "Methods of Measuring Insertion Loss, Phase Shift and Time Delay of Transmission Networks".

ROYAL INSTITUTION (at 21 Albemarle Street, London, W.1), at 9 p.m.—Sir Lawrence Bragg, F.R.S.: "Metal Physics".

Friday, March 19—Saturday, March 20

BRITISH RHEOLOGISTS' CLUB (joint meeting with the TEXTILE INSTITUTE, the SOCIETY OF DYERS AND COLOURISTS, the LEEDS AREA LOCAL SECTIONS of the CHEMICAL SOCIETY and the ROYAL INSTITUTE OF CHEMISTRY, the YORKSHIRE SECTION of the SOCIETY OF CHEMICAL INDUSTRY, and the MANCHESTER AND DISTRICT BRANCH of the INSTITUTE OF PHYSICS, in the Department of Textile Industries, The University, Leeds).—Conference on "Rheology in the Textile Industries".

Saturday, March 20

AMATEUR ENTOMOLOGISTS' SOCIETY (at Buckingham Gate Central School, Wilfred Street, London, S.W.1), at 2 p.m.—Entomological Exhibition.*

INSTITUTION OF CHEMICAL ENGINEERS, NORTH-WESTERN BRANCH (in the Reynolds Hall, College of Technology, Manchester), at 3 p.m.—Mr. N. T. Gridgeman: "Value of Statistics to the Chemical Engineer".

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

SCIENTIST, Grade I (with good honours degree in science or an equivalent qualification)—The Administrative Officer, National Coal Board, Northern Division, Scientific Department, The Grange, Longbenton, Newcastle-upon-Tyne (March 20).

LABORATORY STEWARD FOR THE DEPARTMENT OF ZOOLOGY—The Clerk, Birkbeck College, Breams Buildings, London, E.C.4 (March 22).

RESEARCH ASSISTANT IN THE PROFESSORIAL UNIT—The Secretary, Royal Eye Hospital, St. George's Circus, London, S.E.1 (March 22).

ASSISTANT LECTURER IN HORTICULTURE, an ASSISTANT LECTURER IN POULTRY HUSBANDRY, and an ASSISTANT LECTURER IN RURAL DOMESTIC ECONOMY, including DAIRY HUSBANDRY, at the Essex Institute of Agriculture, Writtle—The Chief Education Officer, County Offices, Chelmsford (March 23).

ASSISTANT (male) IN THE TECHNICAL AND ADVISORY SECTION to assist in putting over the work in progress to scientists, fruit-growers, and the general public—The Secretary, East Malling Research Station, East Malling, Maidstone, Kent (March 27).

LECTURER (Grade II or Grade III) IN ELECTRICAL ENGINEERING—The Secretary and Registrar, The University, Bristol (March 27).

LECTURER IN THEORETICAL CHEMISTRY, a LECTURER IN PURE MATHEMATICS, and a LECTURER IN ZOOLOGY—The Secretary, The University, 38 North Bailey, Durham (March 27).

SENIOR STRESSMEN (2), a RADIO AND ELECTRICAL ENGINEER, and SENIOR DRAUGHTSMEN (2), for work in Australia on the design of small high-speed, jet-propelled aircraft—The Deputy High Commissioner, Australia House, Strand, London, W.C.2 (March 31).

I.C.I. RESEARCH FELLOWSHIPS in biochemistry, chemistry, engineering, pharmacology or physics—The Secretary of University Court, The University, Glasgow (March 31).

LECTURER and ASSISTANT LECTURER IN STATISTICS with experience in the application of statistical methods in the social sciences—The Secretary, London School of Economics, Houghton Street, Aldwych, London, W.C.2 (March 31).

DEMONSTRATOR in each of the DEPARTMENTS OF PHYSICS, CHEMISTRY, BOTANY and ZOOLOGY, at the University College of the West Indies, Jamaica—The Secretary, Inter-University Council for Higher Education in the Colonies, 8 Park Street, London, W.1 (April 1).

LECTURER (Grade III) IN THE DEPARTMENT OF GEOGRAPHY—The Clerk, Birkbeck College, Breams Buildings, London, E.C.4 (April 3).

SENIOR ASSISTANTS (one in Bacteriology and one in Pathology), and a SENIOR LECTURER IN PHYSIOLOGY, in the University of Cape Town—The Secretary, Universities Bureau of the British Empire, 8 Park Street, London, W.1 (April 5).

SECOND ASSISTANT AT THE BOLUS HERBARIUM, University of Cape Town—The Secretary, Universities Bureau of the British Empire, 8 Park Street, London, W.1 (April 5).

CHAIR OF PSYCHIATRY—The Registrar, The University, Manchester 13 (April 9).

RESEARCH FELLOWSHIP IN SCIENCE—The Secretary, The University, 38 North Bailey, Durham (April 10).

ASSISTANT DIRECTOR, ENGINEERING CLASS, in the Ministry of Supply—The Secretary, Civil Service Commission, Scientific Branch, 27 Grosvenor Square, London, W.1, quoting No. 2132 (April 12).

PROFESSOR OF CHEMISTRY—The Registrar, University College, Singleton Park, Swansea (April 17).

LECTURER or ASSISTANT LECTURER IN THE DEPARTMENT OF PHYSICS, and a LECTURER or ASSISTANT LECTURER IN PSYCHOLOGY to work under the Professor of Philosophy—The Registrar, The University, Sheffield (April 24).

LECTURER (Grade II or Grade III) IN STATISTICS, and an ASSISTANT LECTURER (Grade III) IN APPLIED MATHEMATICS—The Registrar, The University, Liverpool (May 15).

CHAIR OF ELECTRICAL ENGINEERING—The Secretary, Royal Technical College, Glasgow.

ASSISTANT SEROLOGIST—The Secretary, Wright-Fleming Institute of Microbiology, St. Mary's Hospital, Paddington, London, W.2.

PHYSICIST TO THE RADIOTHERAPY CENTRE—The House Governor, Hull Royal Infirmary, Hull.

PHYSICIST to investigate, in collaboration with senior rheologist, physical properties of bovine secretion—The Secretary, National Institute for Research in Dairying, Shinfield, Reading, Berks.

LECTURE ASSISTANT IN THE DEPARTMENT OF CHEMISTRY—The Registrar, University College, Singleton Park, Swansea.

ASSISTANT EDITOR OF "SCIENCE ABSTRACTS" to select and edit abstracts for "Physics Abstracts"—The Secretary, Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

JUNIOR CHEMISTS (2, in Derby and London respectively)—The Scientific Research Manager, Railway Executive (London Midland Region), Euston Station, London, N.W.1.